

THE
ELEMENTS
OF
NAVIGATION.

VOLUME THE SECOND.

THE
ELEMENTS
OF
NAVIGATION;

CONTAINING THE
THEORY and PRACTICE.

With the necessary TABLES,
And COMPENDIUMS for finding
The LATITUDE and LONGITUDE at SEA.

To which is added,
A TREATISE
OF
MARINE FORTIFICATION.

Composed for the Use of
The ROYAL MATHEMATICAL School at CHRIST'S HOSPITAL,
The ROYAL ACADEMY at PORTSMOUTH,
And the GENTLEMEN of the NAVY.

VOL. II.

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The SIXTH EDITION, with ADDITIONS.

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L O N D O N :

Printed for F. WINGRAVE, Successor to Mr. NOURSE, in the Strand;
G. G. and J. ROBINSON, and T. N. LONGMAN, Pater-noster-Row;
W. RICHARDSON, Royal Exchange; and J. SCATCHERD, Ave-Maria-Lane.

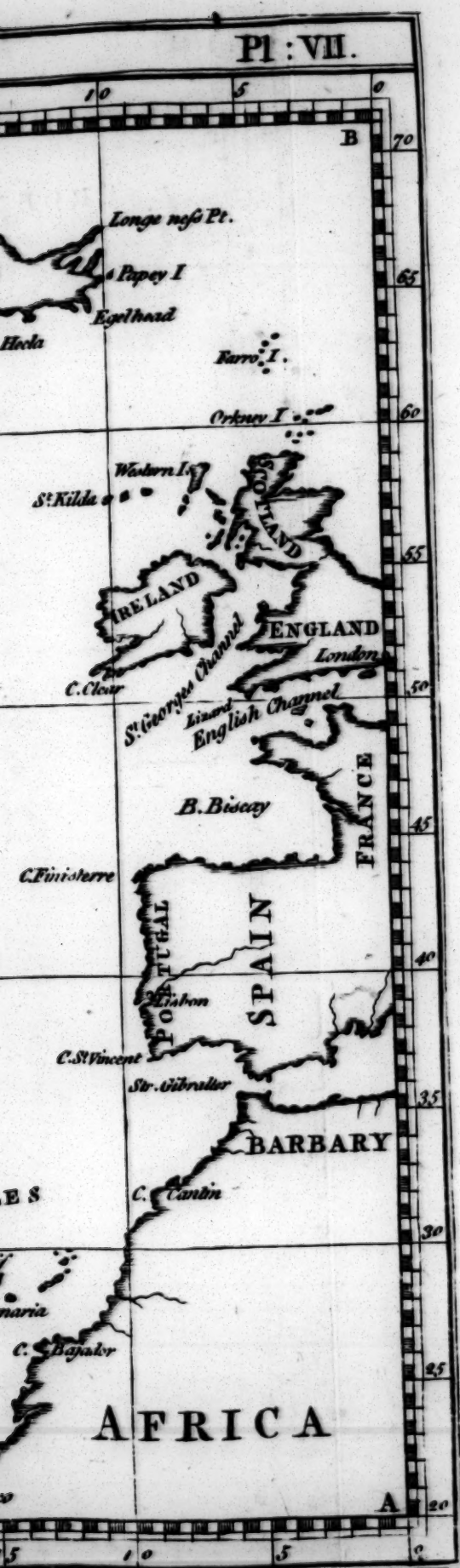
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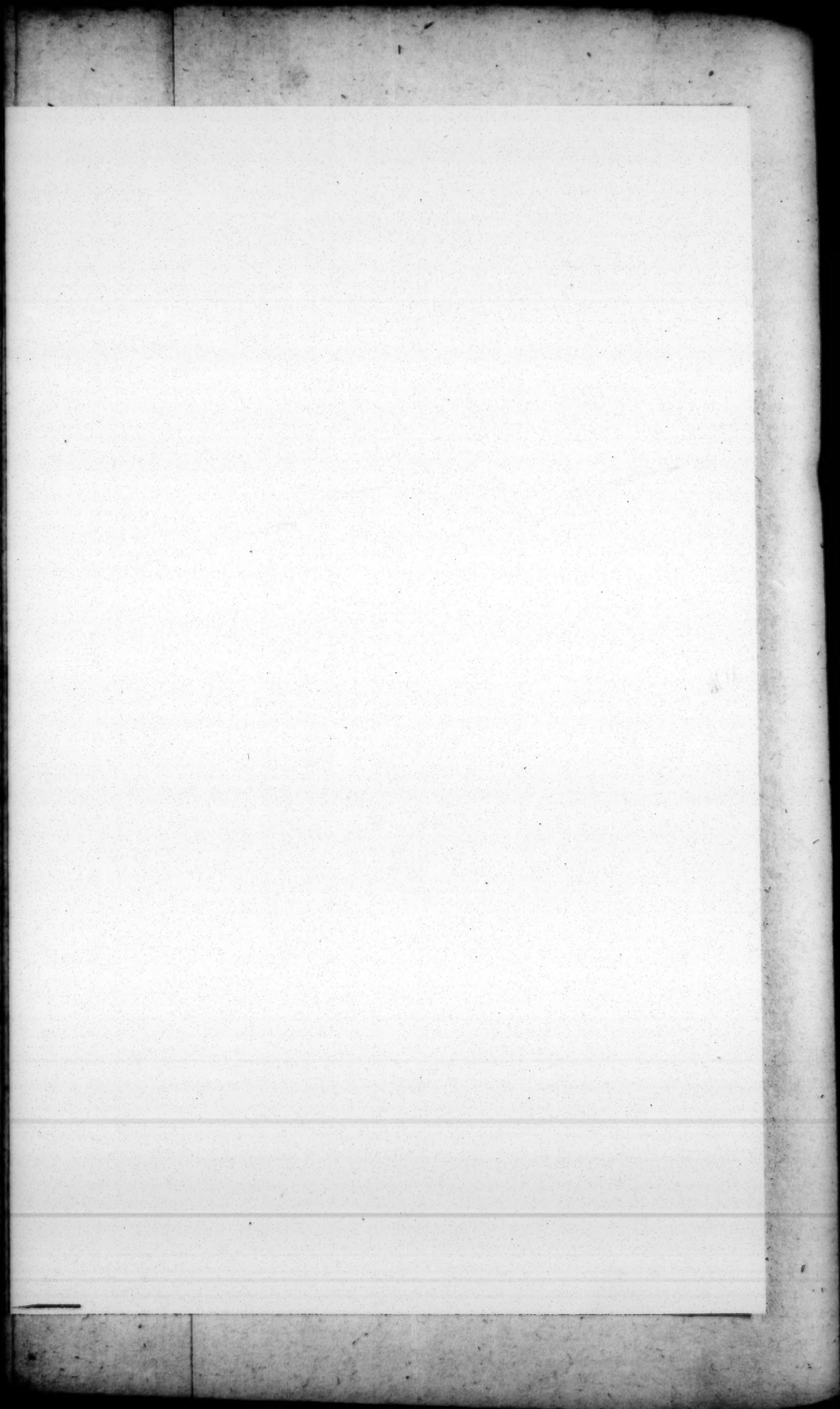
Vol. II

PLANE CHART



F. Jefferys sculp.







THE
ELEMENTS
OF
NAVIGATION.

BOOK VII.
OF PLANE SAILING.

SECTION I.
Definitions and Principles.

1. **NAVIGATION** is the art of conducting a ship from one port to another.

This art may be divided into two parts; namely, Mechanical and Theoretical.

MECHANICAL, or WORKING NAVIGATION, comprehends the art of working a ship; that is, of causing it to observe such motions and directions as are assigned by the Navigator.

This art must be learned on shipboard, and in the practice of sailing.

THEORETICAL NAVIGATION, or the art of Piloting, concerns those methods by which the Navigator, or Pilot, discovers in what track the ship must steer, so as to arrive safe at the intended port.

The art of Piloting is either common or proper.

COMMON PILOTING is that knowledge which teaches how to coast along shore, or to sail within sight of land.

PROPER PILOTING is the art of sailing to distant places through the ocean, and out of sight of land.

The art of proper Piloting, (which partly includes that of common piloting) chiefly depends on a right application of the principles contained in the preceding books.

2. The navigating or conducting of a ship through the Ocean to distant countries, depends on the navigator's being beforehand furnished with the following elements.

1st. A Table of the latitudes and longitudes of the most remarkable parts of the Sea-coasts, Islands, Rocks, Shoals, &c. in the frequented parts of the world.

2d. Maps or Charts of the Seas and Lands; together with the depths of water, and the times and setting of the tides, upon the coasts which he may have occasion to approach.

3d. The use and application of several Instruments necessary to point out the way the ship is to steer, to measure the rate she runs at, and to find the place she is in at any time.

4th. A sufficient stock of mathematical learning to enable him rightly to use the observations that may be deduced from the preceding elements.

The latitudes and longitudes of places cannot be otherwise obtained, than from proper observations made by persons who have been in those places: consequently, the collecting of a sufficient number of these must be the work of many ages. And hence arises the great uncertainty of the position of many places, and even of the little knowledge we have of many parts on the surface of the Terraqueous globe. See the Geographical Table at the end of Book VI.

3. The Maps of Countries, and the Charts of the Oceans and their boundaries, are made chiefly from the catalogue of the latitudes and longitudes of places. But where these are partly wanting, and a good collection of the positions and distances of places can be obtained, those places may be inserted in the map as truly as the others, the latitudes and longitudes of which are known.

The most natural way of delineating the surface of the Earth, is to do it on a sphere; for then every place in the Globe, laid down by its latitude and longitude, will have the same position with respect to other places, which they really have on the surface of the Earth. But as a Globe is a bulky thing, and not so easily managed, or worked upon, as a plane, therefore has the representation of the surface of the Earth been made on planes, and these are called *Maps* or *Charts*.

In the constructing Maps and Charts great care should be taken, that the several parts in them preserve their position one to the other in the same order as they do on the Earth; and it is likely, that the finding out of proper methods to do this gave rise to the several methods of projection.

4. There are many ways of constructing Maps and Charts; but they chiefly depend on two principles.

First, From considering the Earth as a large extended flat surface: The Charts made on this supposition are usually called PLANE CHARTS.

Secondly, From considering the Earth as a sphere: The Charts made on this principle are sometimes called GLOBULAR CHARTS, or MERCA-TOR'S CHARTS, or REDUCED CHARTS, or PROJECTED CHARTS.

Plane Charts, when made for any large extent of several degrees in high latitudes are very erroneous; for in them the difference of longitude between any two Meridians, taken at the Equator, is used as the distance of those meridians in all latitudes; and consequently the distances of places in high latitudes will be too great, and their due positions will not be preserved: but Charts made for a small part, as a degree or two in length and breadth, may be reckoned as tolerably exact, especially if those places be within the *Torrid Zone*; nay, a Plane Chart made of all this Zone will differ but little from the truth.

SECTION II.

5. *The Construction and Use of the Plane Charts.*

CONSTRUCTION.

1st. Having determined the limits of the Chart, that is, how many degrees of latitude and longitude, or meridional distance (they being in this Chart the same), it is to contain: Suppose from the lat. of 20° N. to the lat. of 71° N.; and from the longitude of London in 0° deg. to the lon. of 50° W.; then chuse a scale of equal parts, by which the Chart may be contained within the size of the sheet of paper on which it is intended to be drawn. In the Chart annexed, see Pl. VII. the scale is such, that each degree of latitude and longitude is $\frac{1}{6}$ part of an inch.

2d. Make a parallelogram (II. 69) ABCD, the length of which AB from north to south shall contain 51 degrees, the difference of latitude between the limits of 20° and 71° ; and the breadth AD from east to west shall contain the proposed 50 degrees of longitude, the degrees being taken from the said scale of 8 degrees to an inch; and this parallelogram will be the boundaries of the Chart.

3d. About the boundaries of the Chart make (II. 81) scales containing the degrees, halves and quarters of degrees (if the scale is large enough); drawing lines across the Chart through every 5 or 10 degrees; let the degrees of latitude and longitude have their respective numbers annexed, and the sheet is then fitted to receive the places intended to be delineated thereon.

4th. On a strait slip of pasteboard, or stiff paper, let the scale of the degrees and parts of degrees of longitude, in the line AD, be laid close to the edge; and the divisions numbered from the right hand towards the left being all west longitude.

5th. Seek in the Geographical Table (at the end of Book VI.) for the latitudes and longitudes of the places contained within the proposed limits; and let them be written out in the order in which they increase in latitude.

6th. Then, to lay down any place, lay the edge of the pasteboard scale to the divisions on each side the Chart, shewing the latitude of the place; so that the beginning of its divisions fall on the right hand border AB; and against the division shewing the longitude of the given place make a point, and this gives the position of the place proposed; and in like manner are all the other places to be laid down.

7th. Draw waving lines from one point to the other, where the coast is contiguous, and thus the representation of the lands within the proposed limits will be delineated.

8th. Write the names to the respective parts, and in some convenient place insert a compass, and the Chart will be completed.

The Use of the Plane Chart.

6. *To find the lat. and long. of any proposed place in the Chart.*

Take with a pair of compasses the least distance between the given place and some parallel of latitude; this distance applied (the same way) to the graduated meridian on the border of the Chart, keeping one point on the same parallel of latitude, the other point will shew the degrees of latitude the proposed place is in.

And in like manner, the distance between the given place and some meridian, applied (the same way) to the graduated parallel on the top or bottom of the Chart, will shew its degrees of longitude.

Thus the distance between Cape Finisterre and the parallel of latitude of 40° , laid on the border from 40° upward, gives $43^{\circ} 15'$ N. for Cape Finisterre's latitude: And the distance of the Cape from the meridian passing through 10° of longitude, being laid on the bottom border from 10° toward the right, gives $9^{\circ} 20'$ W. for the longitude.

7. *Two places being given, suppose Cape Clear and the Island of St. Michael's, one of the Azores, to find the bearing and distance between them.*

Lay a ruler by the two places, C. Clear and St. Michael's, take the nearest distance between the center of the compass and the edge of the ruler; in this position slide one point along the ruler, and the other point will run along the point of the compass shewing the bearing, which in this case is S. W.; that is, St. Michael's lies to the S. W. of C. Clear, or C. Clear to the N. E. of St. Michael's.

The distance between the two places applied to the graduated parallel from 0 degrees, will give the number of degrees, which converted into miles shews their distance.

Thus the distance from Cape Clear to St. Michael's will be found to be about $17^{\circ} 10'$, which multiplied by 60 gives 1030 miles.

8. *The distance sailed on a given course, and from a given place, being known, to find the place the ship is in. Thus suppose a ship sails from Cape Clear S. W. for 1030 miles: Required her present place.*

Reduce the given miles (1030) into degrees and minutes, and take them ($17^{\circ} 10'$) with one pair of compasses from the graduated scales.

Lay a ruler by the center and the given point of the compass (S. W.); take the nearest distance between (Cape Clear) the place sailed from and the edge of the ruler with another pair of compasses; in this position, slide one point along the ruler until the other point has got as far distant from the given place as is the given distance, which is found by applying the opening of the other pair of compasses from (Cape Clear) the given place, till the points of both pair of compasses meet; and that will give the present place of the ship, which will be found in the latitude and longitude of St. Michael's; and these are known by Art. 6.

The Mariner working by the preceding precepts, will preserve his chart free from a multitude of lines: But when this is not regarded (as indeed it is scarcely worth while), the operations will become somewhat shorter.

9. *The latitude of a place (A), and its bearing from a given place (B) being known; to find the place (A) on the chart, and its distance from (B).*

Through the given place B draw a line parallel to the given point of the compass or bearing; then an east and west line drawn through the latitude of A, its intersection with the former line will give the place sought. The distance may be measured, as in Art. 7.

10. *The latitude of a place (A), and its distance from a given place (B) being known; to find the place of A on the chart.*

Draw an east and west line through the latitude of A; take the given distance in degrees from the graduated scale; then this distance being applied from the given place B, will cut the said east and west line in the required place of A.

11. *The longitude of a place (A), and its distance from a given place (B) being known; to find the place of A on the chart.*

Draw a meridian through the longitude of A; then the given distance taken as before, and applied from B, will cut the said meridian in the required place of A.

12. *The longitude of a place (A), and its bearing from a given place (B) being known; to find the place of A on the chart.*

Through the given place B draw the given bearing. (7)

Draw a meridian through the longitude of A, and its intersection with the said bearing will be the place of A.

And in this manner may every possible case of sailing by the plane chart be readily solved. But as the accuracy of these solutions cannot be depended upon nearer than five or six minutes more or less than the truth; the more careful Navigators depend on the computations given in the following sections,

SECTION III.

Of Plane Sailing.

13. PLANE SAILING is the art of navigating a ship upon principles deduced from the notion of the Earth's being an extended plane.

On this supposition, the meridians are esteemed as parallel right lines, the parallels of latitude are at right angles to the meridians, the lengths of the degrees on the meridians, equator, and parallels of latitude, are every where equal; and the degrees of longitude are reckoned on the parallels of latitude as well as on the equator.

14. The PLANE CHART is a map, or representation, of the several parts of the Earth laid down from these principles, according to their latitudes and longitudes, on a sheet of paper, or other flat surface. (5)

When the parts of the Earth are thus delineated on a plane, it is easy to see the track by which the ship may go from one place to another; and also what angle this track makes with the meridian: ships at sea are kept in this track, or path, by the help of an instrument called the Mariner's Compass.

15. The MARINER'S COMPASS is an artificial representation of the horizon of every place, by the means of a circular piece of paper called a Card, divided like the horizon into degrees and points, which are called Rhumbs. Now the card being properly fixed to a piece of steel called a Needle, that has been touched with a loadstone, (the property of which is to cause one end of the needle, so touched, to point towards the north, when turning freely on something supporting it), all the points of the card will be directed toward their corresponding points of the horizon.

From this construction of the Mariner's Compass it follows, that in every place the north point of the card shews the position of the meridian in that place; and some one rhumb, or point of the card, will coincide with, or be directed along, the track that makes any given angle with the meridian: Consequently, by the help of the card, or compass, a ship may be kept on any proposed track, or course.

16. A RHUMB LINE is a right line drawn from the center of the compass to the horizon; and is named from the point of the horizon it falls in with.

17. The COURSE is an angle which the Rhumb line the ship sails on makes with the meridian, and it is sometimes reckoned in degrees, and sometimes in points of the compass.

18. DISTANCE is the number of leagues, miles, &c. intercepted between two places reckoned on a Rhumb; or it is the way or length a ship has gone on a direct course in a given time.

19. DIFFERENCE OF LATITUDE is the distance which a ship has made north or south of the place she set out from; and it is reckoned in miles and parts of a mile on a meridian.

20. DEPARTURE is the east or west distance which a ship has made from the meridian of the place she departed from, reckoned on the parallel of latitude which she is arrived in, and in the plane chart it is the same as the difference of longitude,

21. If

21. If a ship sails either due north or south, she sails on a meridian, makes no departure, and her distance and difference of latitude are the same.

If a ship sails either due east or west, she runs on a parallel of latitude, makes no difference of latitude, and her departure and distance are the same.

The difference of latitude and departure always make the legs of a right-angled triangle, the hypotenuse of which is the distance the ship has sailed.

When the course is 45 degrees, or 4 points, the difference of latitude and departure are equal.

When the course is less than 45 degrees, or 4 points, the difference of latitude is greater than the departure.

But when the course is greater than 4 points, or 45 degrees, the departure is greater than the difference of latitude.

22. When a figure relating to a ship's course is to be constructed, it must first be considered whether the ship is sailing northward or southward; and whether she goes to the eastward or westward of the place she departed from; for the lines in the figure must be drawn accordingly.

Thus. Let the upper part of the paper, or what the figure is drawn on, always represent the north, then the lower part will be south, the right hand side east, and the left hand side the west.

Draw a north and south line to express the meridian of the place the ship sails from; then if the course is to the southward, mark the upper end of the line for the place sailed from; but if the course is northward, mark the lower end for that place.

Through the point sailed from draw a line perpendicular to the meridian to represent the parallel of latitude of that place; and from the same point, with the chord of 60 degrees, describe a quadrantal arc on the east side of the meridian, if the course is eastward, or on the west side, if the course is to the westward.

When the course is given, the chord of the degrees, or points expressing it, is to be taken with a pair of compasses, either from the scale of chords or of rhumbs*: and is always to be laid off on the quadrantal arc, beginning at the meridian.

The line expressing the distance the ship has run, is always to be drawn from the center of the quadrant, or point sailed from, through that point of its arc which limits the course.

The difference of latitude, in leagues or miles, taken with the compasses from a scale of equal parts, is ever to be laid on the meridian, reckoning from the center of the quadrant.

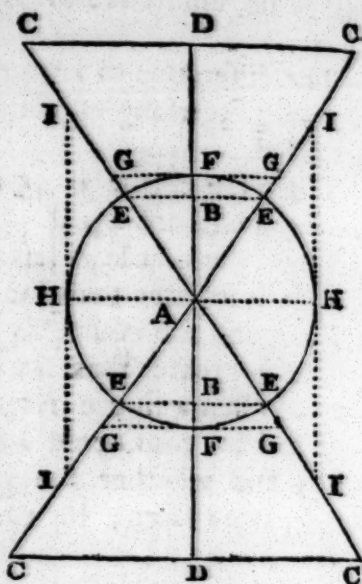
* A quadrant, or arc of 90° , being divided into eight equal parts, and each of these into quarters; then if from one end of the arc the several divisions be transferred to the chord of 90° , as in Book III. Art. 18. a line of rhumbs is constructed, the use of which is the same as that of the chords, namely, to make an angle whose measure is given in points instead of degrees.

The departure is a right line parallel to the east and west line before drawn, joining the ends of the lines expressing the distance and difference of latitude.

23. In the annexed figure, suppose the circle $FHFH$ to represent the horizon of the place A , from whence the ship sails; AC the rhumb she sails on, and c the place come to; then HH represents the parallel of latitude she sailed from, cc the parallel of the latitude arrived in: So that AD becomes the difference of latitude, DC the departure, AC the distance sailed, the angle DAC is the course, and the angle DCA is the complement of the course.

These particulars will be alike represented, whether the ship sails in the N. E. or N. W. S. E. or S. W. quarter of the horizon.

Hence it is evident, that the difference of latitude, departure, and distance, form the sides of a right-angle triangle, whose angles are the course, its complement and the right-angle, whose sine is radius; therefore among these four things, *course*, *distance*, *diff. lat.* and *departure*, any two of them being given, the rest are to be found by plane trigonometry.



24.

Of the Traverse Table.

For the ready working of any single course, there is a table, called the *Traverse Table*, usually annexed to Treatises of this kind; which is so contrived, that by finding in it the given course and a distance not exceeding 100 miles, the diff. lat. and departure is had by inspection. The course is to be found at the top of the table, when under 4 points, or 45 deg; but at the bottom of the table when it exceeds 45 deg. Each column signed with a course consists of two parts, one for the diff. lat., marked *Lat.*: the other for the departure, marked *Dep.*; which names are both at the top and bottom of these columns. The distance is to be found in the column marked *Dist.* next the margin of the page.

This table will serve for greater distances, by taking their halves, thirds, fourths, &c. and doubling, tripling, quadrupling, &c. the diff. lat. and departure found to those parts of the distance.

The traverse table contained in this Treatise, at the end of Book VII. has the distances continued to 120, which is a number more capable of subdivisions than 100: Besides, the table is divided into two parts; the first contains the whole points and quarter points in a quadrant; and the second part is fitted to every degree and quarter of a degree in the quadrant; whence the course and distance, resulting from a day's work, is more accurately obtained than by the common traverse tables.

25. All the proportions that can arise in plane sailing are exhibited in the following table; they refer to the preceding figure, where AE , AF , or AH represent the radius of the tables, EB the sine of the course, GF its tangent, and AG its secant; AB stands for the sine of the complement of the course, HI its tangent, and AI its secant.

These proportions are here inserted, to exercise the learner in reasoning on the relations subsisting between these lines and those representing the distance, departure, and difference of latitude: but in what follows, only the analogies in the first column, and one against the last case in the second column, will be used; the others being rather matters of curiosity than use.

Case	Given	Req.	Solutions by sines	Solutions by tangents and secants
—	—	—	by sim. $\Delta ADC, ABE$	by sim. $\Delta ADC, AFG$ by sim. $\Delta ADC, AHI$
1	$\angle A, AC$	AD DC	AE : AB :: AC : AD AE : EB :: AC : DC	AG : AF :: AC : AD AG : FG :: AC : DC AI : IH :: AC : AD AI : AH :: AC : DC
2	$\angle A, AD$	AC DC	AB : AE :: AD : AC AB : BE :: AD : DC	AF : AG :: AD : AC AF : FG :: AD : DC IH : AI :: AD : AC IH : AH :: AD : DC
3	$\angle A, DC$	AC AD	BE : AE :: DC : AC BE : AB :: DC : AD	FG : AG :: DC : AC FG : AF :: DC : AD AH : AI :: DC : AC AH : HI :: DC : AD
4	AD, AC	$\angle A$ DC	AC : AD :: AE : AB AE : EB :: AC : DC	AD : AC :: AF : AG AF : FG :: AD : DC
5	AC, DC	$\angle A$ AD	AC : DC :: AE : EB AE : AB :: AC : AD	DC : AC :: AH : AI AH : HI :: DC : AD
6	AD, DC	$\angle A$ AC		AD : DC :: AF : FG AF : AG :: AD : AC DC : AD :: AH : HI AH : AI :: DC : AC

26. To assist the learner, the proportions hereafter used are given in their nautical terms,

Case	Given	Required	SOLUTIONS.
1	Course & Distance	Diff. lat. Depart.	Rad. : Dist. :: Cos. Cou. : Diff. lat. N° I. Rad. : Dist. :: sin. Cou. : Depart. N° II.
2	Course Diff. lat.	Distance Depart.	Cos. Cou. : Diff. lat. :: Rad. : Distance. N° III. Cos. Cou. : Diff. lat. :: sin. Cou. : Depart. or by N° II.
3	Course Depart.	Distance Diff. lat.	Sin. Cou. : Depart. :: Rad. : Dist. N° V. Sin. Cou. : Depart. :: Cos. Cou. : Diff. lat. or by N° I.
4	Distance Diff. lat.	Course Depart.	Dist. : Rad. :: Diff. lat. : Cos. Cou. N° VII. Rad. : Dist. :: sin. Cou. : Depart. by N° II.
5	Distance Depart.	Course Diff. lat.	Dist. : Rad. :: Depart. : sin. Cou. N° IX. Rad. : Dist. :: Cos. Cou. : Diff. lat. by N° I.
6	Diff. lat. Depart.	Course Distance	Diff. lat. : Depart. :: Rad. : tan. Cou. N° XI. Sin. Cou. : Depart. :: Rad. : Dist. by N° V.

These proportions (or Canons as they are usually called by Mariners) are applied to the numeral solutions of all the varieties of single courses in the following section.

The numbers I, II, &c. placed at the end of these Canons, shew which proportion they refer to in the upper table; reckoning two in each case.

27. A TABLE of the angles, which every rhumb, or point of the compass, makes with the meridian.

NORTH.	SOUTH.	Points.	D. M.	NORTH.	SOUTH.
		0 $\frac{1}{4}$	2 49		
		0 $\frac{1}{2}$	5 37 $\frac{1}{2}$		
		0 $\frac{3}{4}$	8 26		
N. b E.	S. b. E.	1 0	11 15	N. b. W.	S. b. W.
		1 $\frac{1}{4}$	14 04		
		1 $\frac{1}{2}$	16 52 $\frac{1}{2}$		
		1 $\frac{3}{4}$	19 41		
N. N. E.	S. S. E.	2 0	22 30	N. N. W.	S. S. W.
		2 $\frac{1}{4}$	25 19		
		2 $\frac{1}{2}$	28 07 $\frac{1}{2}$		
		2 $\frac{3}{4}$	30 56		
N. E. b N.	S. E. b. S.	3 0	33 45	N. W. b. N.	S. W. b. S.
		3 $\frac{1}{4}$	36 34		
		3 $\frac{1}{2}$	39 22 $\frac{1}{2}$		
		3 $\frac{3}{4}$	42 11		
N. E.	S. E.	4 0	45 00	N. W.	S. W.
		4 $\frac{1}{4}$	47 49		
		4 $\frac{1}{2}$	50 37 $\frac{1}{2}$		
		4 $\frac{3}{4}$	53 26		
N. E. b. E.	S. E. b. E.	5 0	56 15	N. W. b. W.	S. W. b. W.
		5 $\frac{1}{4}$	59 04		
		5 $\frac{1}{2}$	61 52 $\frac{1}{2}$		
		5 $\frac{3}{4}$	64 41		
E. N. E.	E. S. E.	6 0	67 30	W. N. W.	W. S. W.
		6 $\frac{1}{4}$	70 19		
		6 $\frac{1}{2}$	73 07 $\frac{1}{2}$		
		6 $\frac{3}{4}$	75 56		
E. b. N.	E. b. S.	7 0	78 45	W. b. N.	W. b. S.
		7 $\frac{1}{4}$	81 34		
		7 $\frac{1}{2}$	84 22 $\frac{1}{2}$		
		7 $\frac{3}{4}$	87 11		
E A S T.	E A S T.	8 0	90 00	W E S T.	W E S T.

Before the learner begins to work the cases of plane sailing, he should be so well acquainted with the compass, or this table, as to be able readily to tell how many points any of these courses or rhumbs are distant from the meridian, or from the parallel.

SECTION

SECTION IV.

Of Single Courses.

28. CASE I. Given the course steered, and the distance run :
Required the difference of latitude and departure.

EXAM. A ship from the latitude $47^{\circ} 30' N.$ has sailed S. W. by S. 98 miles: What lat. is she in, and what dep. has she made?

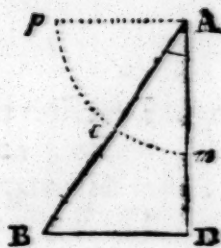
By the TRAVERSE TABLE.

Find the given course at the top or bottom of the table among the points or degrees; and in that column, right against the distance taken in its column, stand the diff. lat. and departure in their columns.

Thus the course is S. W. by S. or 3 points, in which column, and against the distances 98 in the column of distances, stand 81,5 miles for the diff. lat.; and 54,45 miles for the departure.

By CONSTRUCTION. (22)

1. Draw the meridian AD, and make the quadrant $Amcp.$
 2. Make mc = rhumb of 3 points, and through c draw AB equal to 98 miles.
 3. Draw BD parallel to pA , meeting AD in D.
- Then AD, the diff. lat. measures about $81\frac{1}{2}$ miles.
And DB, the departure, measures about 54,4 miles.



By COMPUTATION.

The course being 3 points = $33^{\circ} 45'$.			The comp. course is 5pts. = $56^{\circ} 15'$		
To find the diff. latitude.			To find the departure.		
As rad.	= $90^{\circ} 00'$	10,00000	As rad.	= $90^{\circ} 00'$	10,00000
To diff.	= 98 m.	1,99123	To dist.	= 98 m.	1,99123
So co-f. co.	= $33^{\circ} 45'$	9,91985	So sin. co.	= $33^{\circ} 45'$	9,74474
To diff. lat. = 81,48			To dep. = 54,45		
		1,91108			1,73597

By GUNTER'S SCALE.

On the line of fine Rhumbs*, the extent from Radius, or 8 points, to 3 points, applied to the line of numbers, will reach from 98, in either interval, to 54,4.

And the extent from 8 points, to 5 points among the Rhumbs, reaches from 98 to 81,5 on the line of numbers.

Or thus. The extent from Radius, or 8 points, in the S. R. to 98 in the Numb. will reach from 3 points in the Rhumbs to 54,4 in the Numb. and the same extent will reach from 5 points in the Rh. to 81,5 in the Numb.

81
60 = $1^{\circ} 21'$. The lat. from $47^{\circ} 30' N.$
diff. lat. 1 21 S.

Lat. in $46^{\circ} 9' N.$ Dep. 54,4 miles West.

* The lines on the Gunter's scale marked S. R. and T. R. signifying *Sine Rhumbs* and *Tangent Rhumbs*, are the logarithmic sines and tangents answering to the degrees and minutes in each point and quarter point of the Compass, transferred from the scales of log. sines and log. tangents.

29. CASE II. Given the course steered, and difference of latitude:
Required the distance run, and the departure.

EXAM. *A ship has sailed S. E. by S. from the lat. $47^{\circ} 30'$ N. to the lat. $46^{\circ} 08'$ N. What distance has she run, and what departure has she made?*

By the TRAVERSE TABLE.

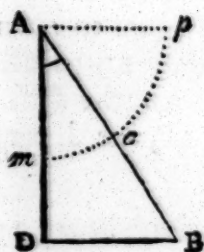
Find the course among the degrees, and the diff. lat. in its column, right against which stand the departure and distance in their columns.

Now taking $46^{\circ} 08'$ from $47^{\circ} 30'$, remains $1^{\circ} 22' = 82$ m. the diff. lat.

Then the course S. E. b. S. is 3 points, under which in the column of lat. the nearest number to 82 is 82,3, the corresponding departure is 55, and the distance 99 miles.

By CONSTRUCTION.

- 1st. Describe the quadrant Amp .
 - 2d. Make mc = rhumb of 3 points, and continue Am till $AD = 82$ miles.
 - 3d. Through D draw DB parallel to Ap , meeting the line AB drawn through c in the point B .
- Then the distance AB measures about 99 miles.
And the departure DB measures about 55 miles.



By COMPUTATION.

The course 3 points = $33^{\circ} 45'$			The comp. course is 5 pts. = $56^{\circ} 15'$		
To find the distance.			To find the departure.		
As co-f. co.	= $33^{\circ} 45'$	0,08015	As co-f. co.	= $33^{\circ} 45'$	0,08015
To diff. lat.	= 82 m.	1,91381	To diff. lat.	= 82 m.	1,91381
So rad.	= $90^{\circ} 00'$	10,00000	So fin. co.	= $33^{\circ} 45'$	9,74474
To dist.	= 98,62	1,99396	To dep.	= 54,79	1,73870

By GUNTER'S SCALE.

On the line of fine rhumbs, the extent from 5 points to 8 points, or radius, will, on the line of numbers, reach from 82 to 99.

And the extent from 5 points to 3 points on the S. R. will reach from 82 to 55 on the line of numbers.

Or thus. The extent from 5 points in the fine rhumbs, to 82 miles in the line of numbers, will reach from 8 points in those rhumbs, to 99 in the numbers; and the same extent will reach from 3 points in the rhumbs to 55 in the numbers.

Note. In all these cases, wherever the co-f. course is used, the deg. put down is the course itself, yet the log. belongs to the comp. of that course.

30. CASE

30. CASE III. Given the course steered, and the departure :
Required the dist. run, and diff. latitude.

EXAM. A ship from lat. $47^{\circ} 30' N.$ sailing *N. W. b. W.* finds she has made 82 miles of departure : What is her distance run, and what lat. is she now in ?

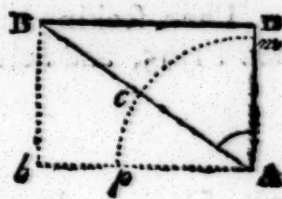
By the TRAVERSE TABLE.

Find the course among the degrees, and the departure in its column ; right against which stand the difference of latitude, and the distance in their respective columns.

Now the course *N. W. b. W.* is 5 points, over which, in the column of departure, the nearest number to 82, is 82,3 ; and the corresponding diff. latitude is 55 miles, and the distance is 99 miles.

By CONSTRUCTION.

- 1st. Describe the quadrantal arc Amc .
- 2d. Make mc = rhumb of 5 points, and continue Ap till $Ab=82$ miles.
- 3d. Through b draw bb parallel to Am , meeting the line AB drawn through c , in B .
- 4th. Through B draw BD parallel to bA , meeting Am continued, in D .



Then the distance AB measures about 99 miles.
And the diff. lat. AD measures about 55 miles.

By COMPUTATION.

The course 5 points is $56^{\circ} 15'$			The comp. course is 3 pts. = $33^{\circ} 45'$.		
To find the distance.			To find the diff. latitude.		
As fin. co.	= $56^{\circ} 15'$	0,08015	As fin. co.	= $56^{\circ} 15'$	0,08015
To dep.	= 82 m.	1,91381	To dep.	= 82 m.	1,91381
So rad.	= $90^{\circ} 00'$	10,00000	So co-f. co.	= $56^{\circ} 15'$	9,74474
To dist.	= 98,62	1,99396	To diff. lat.	= 54,79	1,73870

By GUNTER'S SCALE.

On the line of fine rhumbs, the extent from 5 points to 8 points, or radius, will, on the line of numbers, reach from 82 to 99.

And the extent from 5 points to 3 points on the line S. R. will reach from 82 to 55 on the line of numbers.

Or thus. The extent from 5 points in the fine rhumbs to 82 miles in the line of numbers, will reach from 8 points in the rhumbs to 99 in the numbers : And the same extent will reach from 3 points in the rhumbs to 55 in the numbers.

Lat. from $47^{\circ} 30' N.$
Diff. lat. $2 55 N.$

Lat. in $48 25$

31. CASE

31. CASE IV. Given the distance and difference of latitude :
Required the course and departure.

EXAM. A ship from lat. $47^{\circ} 20' N.$ sails between the north and east 98 miles, and is arrived in lat. $48^{\circ} 42' N.$ What course did she steer, and what departure has she made?

By the TRAVERSE TABLE.

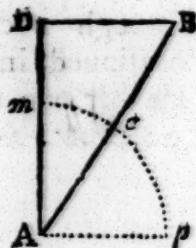
Seek in the table, till against the distance taken in its column be found the given diff. lat. in one of the following columns; and adjoining to it stands the departure, which, if less than the diff. lat. the course is found at the top of the column; but if greater, the course is found at the bottom.

Now having taken $47^{\circ} 20'$ from $48^{\circ} 42'$, leaves $1^{\circ} 22' = 82$ m. the diff. lat.

Then seeking till against dist. 98 stands lat. 82, the nearest will be lat. 81.95, and here the departure is 53.73 m. and the course is $33^{\circ} 15'$.

By CONSTRUCTION.

- 1st. Describe the quadrant Amp .
 - 2d. Continue Am , till $AD = 82$ m.
 - 3d. Through D draw DB parallel to Ap .
 - 4th. On A with the distance 98 cut DB in B .
- Then the departure DB measures about 53 m.
And the course DAB is measured by the arc mc of about 33° .



By COMPUTATION.

To find the course.			To find the departure.		
As dist. ..	= 98 m.	8,00877	As rad. ..	= $90^{\circ} 00'$	10,00000
To rad. ..	= $90^{\circ} 00'$	10,00000	To dist. ..	= 98 m.	1,99123
So diff. lat. = 82 m.		1,91381	So sin. co. = $33^{\circ} 12'$		9,73843
To co-f. co. = $33^{\circ} 12'$		9,92258	To dep. ..	= 53,66	1,72966

By GUNTER'S SCALE.

On the line of numbers, the extent from 98 m. to 82 m. will, on the line of sines, reach from 90, or radius, to about 57° degrees.

And the extent on the line of sines, from 90° to 33° , will reach on the line of numbers from 98 m. to about $53\frac{1}{2}$ miles.

Or thus. The extent from 98 m. in the line of numbers, to 90° in the line of sines, will reach from 82 m. in the numbers to about 57° in the sines: And the same extent will reach from about 33° in the sines, to about $53\frac{1}{2}$ in the numbers.

So that the course is N. $33^{\circ} 12' E.$ or N. E. b. N. nearly.

And the departure is N. 53,66 miles to the Eastward.

32. CASE V. Given the distance and departure :
Required the course, and difference of latitude.

EXAM. From the lat $50^{\circ} 13' N.$ a ship, in sailing between the south and east 98 miles, makes her departure 82 miles: What course did she keep, and what lat. is she arrived at?

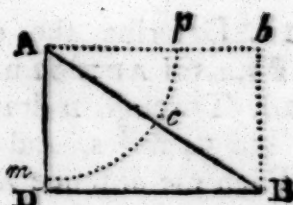
By the TRAVERSE TABLE.

Seek in the table, till against the distance, taken in its column, be found the given departure in one of the following columns, and adjoining to it stands the diff. lat. which if greater than the departure, the course is found at the top of the column; but if less, the course is found at the bottom.

Now seeking till against the dist. 98 stands 82, the nearest will be 81,95, signed Dep. at bottom; and here the diff. lat. is 53,73 m. and the course is $56^{\circ} 45'$.

By CONSTRUCTION.

- 1st. Describe the quadrant $Amcp$.
- 2d. Continue Ap , till $Ab=82$ m.; and through b draw bB parallel to Am .
- 3d. From A with the dist. 98 m. cut bB in B .
- 4th. Through B draw BD parallel to Ab , meeting Am continued, in D .



Then the diff. lat. AD measures about 53 miles.
And the course DAB is measured by the arc mc of about 57° .

By COMPUTATION.

To find the course.			To find the diff. lat.		
As dist.	= 98 m.	8,00877	As rad.	= $90^{\circ} 00'$	10,00000
To rad.	= $90^{\circ} 00'$	10,00000	To dist.	= 98 m.	1,99123
So dep.	= 82 m.	1,91381	So co-f. co.	= $56^{\circ} 48'$	9,73843
To fin. co.	= $56^{\circ} 48'$	9,92258	To diff. lat.	= 53,66	1,72966

Then $50^{\circ} 13' N. - 0^{\circ} 54' N. = 49^{\circ} 19' N.$ For 53,66 m. is nearest 54.

By GUNTER'S SCALE.

On the line of numbers, the extent from 98 m. to 82 m. will, on the line of fines, reach from 90° , or radius, to about 57 degrees.

And the extent on the line of fines, from 90° to 33° , will reach from 98 m. to about $53\frac{1}{2}$ m. on the line of numbers.

Or thus. The extent from 98 m. in the line of numbers to 90° in the line of fines, will reach from 82 m. in the numbers, to about 57° in the fines: And the same extent will reach from about 33° in the fines, to about $53\frac{1}{2}$ m. in the numbers.

So that the course is S. $56^{\circ} 48'$ E. or S. E. b. E. nearly.

And the latitude arrived in is $49^{\circ} 19' N.$

33. CASE VI. Given the difference of latitude and departure:
Required the course and distance.

EXAM. A ship from lat. $48^{\circ} 32' N.$ is arrived in lat. $49^{\circ} 54' N.$ and is got 54 miles to the westward of her departed meridian: What course did she steer, and what is the direct distance she has run?

By the TRAVERSE TABLE.

Seek in the table till the given diff. lat. and departure are found together in their respective columns: then right against them will be found the distance in its column, and the course stands among the degrees at the top or bottom of the column, where the diff. lat. and depart. were found.

Now $48^{\circ} 32'$ taken from $49^{\circ} 54'$, leave $1^{\circ} 22' = 82$ m. the diff. lat.

Then in the table it will be found, that the numbers standing together the nearest to 82 and 54, are 81,95 and 53,73; the distance answering to these is 98 m. and the course is $33^{\circ} 15'$.

By CONSTRUCTION.

1st. Describe the quadrant $Amcp$, and continue Am till $AD = 82$ m.

2d. Through D draw BD parallel to Ap , and equal to 54 miles, and draw AB .

Then the distance AB measures about 98 miles.

And the course DAB is measured by the arc mc of about 33° .



By COMPUTATION.

To find the course.			To find the distance.		
As dif. lat.	= 82 m.	8,08619	As fin. co.	= $33^{\circ} 22'$	0,25964
To depart.	= 54 m.	1,73239	To depart.	= 54 m.	1,73239
So rad.	= $90^{\circ} 00'$	10,00000	So rad.	= $90^{\circ} 00'$	10,00000
To tan. co.	= 33,22	9,81858	To dist.	= 98,18	1,99203

By GUNTER'S SCALE.

On the line of numbers, the extent from 82 m. to 54 m. will reach on the line of tangents from 45° to about 33° .

And the extent on the line of sines, from about 33° to 90° , will reach on the line of numbers from 54 m. to about 98 m.

Or thus. The extent from 82 on the line of numbers to 45° in the line of tangents, will reach from 54 in the line of numbers, to about 33° in the line of tangents.

Also, the extent from about 33° in the sines to 54 in the numbers, will reach from 90° in the sines to about 98 m. in the numbers.

So the course is N. $33^{\circ} 22'$ W. or N. W. b. N. nearly.

And the distance is 98,18 miles.

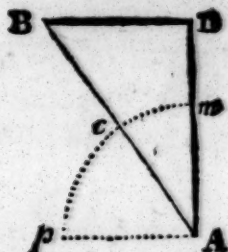
34. Questions to exercise the foregoing Cases.

QUEST. I. Four days ago we were in lat. $3^{\circ} 25' S.$; and have since that time run on a direct course NW. by N. at the rate of 8 miles an hour: Required our present latitude and departure?

One day = 24 hours: Then $24 \times 4 = 96$ hours.
And $96 \times 8 = 768$ miles, the whole distance.

CONSTRUCTION.

- 1st. Draw the meridian AD, and describe the quadrant Amp.
- 2d. Lay off the course 3 points from m to c, and draw the rhumb line AB.
- 3d. On the rhumb line lay the distance from A to B, and draw DB parallel to pA.



COMPUTATION.

As rad.	= $90^{\circ} 00'$	10,00000	As rad.	= $90^{\circ} 00'$	10,00000
To dist.	= 768 m.	2,88536	To dist.	= 768 m.	2,88536
So cof. co.	= $33^{\circ} 45'$	9,91985	So fin. co.	= $33^{\circ} 45'$	9,74474
To diff. lat.	= 638,6 m.	2,80521	To dep.	= 426,7 m.	2,63010

$$\text{Now } \frac{639}{60} = 10^{\circ} 39'$$

$$\text{Then lat. from } 3^{\circ} 25' S. \\ \text{diff. lat. } 10^{\circ} 39' N.$$

$$\text{Answer } \left\{ \begin{array}{l} \text{Lat. in } 7^{\circ} 14' N. \\ \text{Depart. } 426,7 \text{ miles.} \end{array} \right.$$

QUEST. II. Yesterday noon we were in lat. $38^{\circ} 32' N.$; and this day at noon we were in lat. $36^{\circ} 56' N.$ we have run on a direct course between the S. and E. $5\frac{1}{2}$ knots * an hour: Required our course and departure?

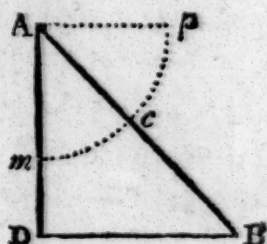
Lat. from $38^{\circ} 32' N.$
Lat. in $36^{\circ} 56' N.$

$$\text{Diff. lat. } 1^{\circ} 36' = 96 \text{ m.}$$

$$\text{24 hours.} \\ 5,5 = 5\frac{1}{2}$$

$$\begin{array}{r} 120 \\ 120 \\ \hline \end{array}$$

$$\text{Dist.} = 132,0 \text{ m.}$$



CONST. Describe the quadrant Amp: draw the meridian AD = 96, and draw DB parallel to Ap; with 132 m. from A, cut DB in B.

COMPUTATION.

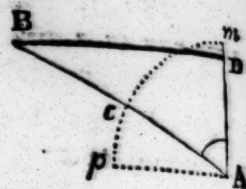
As dist.	= 132 m.	7,87943	As rad.	= $90^{\circ} 00'$	10,00000
To rad.	= $90^{\circ} 00'$	10,00000	To dist.	= 132 m.	2,12057
So diff. lat.	= 96 m.	1,98227	So fin. co.	= $43^{\circ} 20'$	9,83648
To cof. co.	= $43^{\circ} 20'$	9,86170	To dep.	= 90,58	1,95705

$$\text{Answer } \left\{ \begin{array}{l} \text{Course is } S. 43^{\circ} 20' E. \text{ or } SE. \text{ by } S. \frac{1}{4} E. \text{ nearly.} \\ \text{Departure } 90,58 \text{ miles to the Eastward.} \end{array} \right.$$

* A knot is the same as a sea mile, 60 to a degree.

QUEST. III. *A ship in lat. $3^{\circ} 52'$ S. is bound to a port bearing NW. by W. $\frac{1}{2}$ W. in lat. $4^{\circ} 30'$ N.: How far does that port lay to the westward, and what is the ship's distance from it?*

Lat. from $3^{\circ} 52'$ S.
 Lat. to $4^{\circ} 30'$ N.
 Diff. lat. $8^{\circ} 22' = 502$ miles.



CONST. Describe the quadrant $A m p$: Draw the meridian $AD = 502$, and through D draw DB parallel to $A p$: make $mc = 5\frac{1}{2}$ points: Through c draw AB meeting DB in B .

COMPUTATION.

As cof. co.	$= 61^{\circ} 52'$	0,32650	As cof. co.	$= 61^{\circ} 52'$	0,32650
To diff. lat.	$= 502$ m.	2,70070	To diff. lat.	$= 502$ m.	2,70070
So rad.	$= 90^{\circ} 00'$	10,00000	So sin. co.	$= 61^{\circ} 52'$	9,94540
To dist.	$= 1065$	3,02720	To dep.	$= 938,9$	2,97260

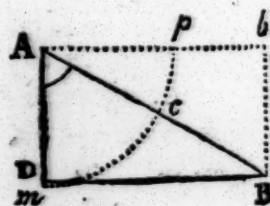
Answer { The port lies 938,9 m. to the westward.
 The direct distance is 1065.

QUEST. IV. *A ship from lat. $30^{\circ} 14'$ N. sails SE. by E. $\frac{1}{2}$ E.; and four days after meets a sloop who had sailed directly east at the rate of 6 miles an hour, she having been, four days before, under the meridian the ship departed from: Required the difference of their rates of sailing, and their present latitude?*

As the ship and sloop sailed from the same meridian, and the sloop runs directly east; therefore her distance will be the ship's departure.

Now in 4 days are 96 hours.

And $96 \times 6 = 576$ miles of departure.



CONST. Describe the quadrant $A m p$.

In $A p$ continued take $Ab = 576$, and draw $b B$ parallel to $A m$.

Make $mc = 5\frac{1}{2}$ points, and through c draw $A c$, meeting $b B$ in B .

Through B draw BD parallel to $b A$ meeting $A m$ continued in D .

COMPUTATION.

As sin. co.	$= 61^{\circ} 52'$	0,05460	As sin. co.	$= 61^{\circ} 52'$	0,05460
To dep.	$= 576$ m.	2,76042	To dep.	$= 576$ m.	2,76042
So rad.	$= 90^{\circ} 00'$	10,00000	So cof. co.	$= 61^{\circ} 52'$	9,67350
To dist.	$= 653,2$ m.	2,81502	To diff. lat.	$= 308$ m.	2,48852

Now $96)653,2$ (6,8 m. per hour the
 [ship's rate.]

772

And $6,8)30,8$ (Then lat. fr. $30^{\circ} 14'$ N.
 diff. lat. $5^{\circ} 08'$ S.

5 8

Lat. in $25^{\circ} 06'$

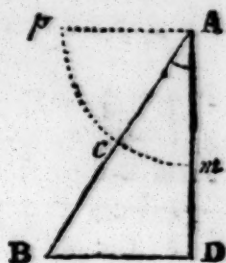
So the difference of their rates of sailing is $\frac{3}{16}$ or $\frac{1}{4}$ of a mile per hour.

QUEST.

QUEST. V. A ship from the lat. $48^{\circ} 17' N.$ sails SW. by S. until she has depressed the north pole two degrees: What direct distance has she run, and how many miles is she got to the westward?

To depress the pole two degrees, the ship must sail southward until her diff. lat. is 2 degrees, or 120 miles.

- CONST. 1st. Draw $AD = \text{diff. lat. } 120 \text{ m.}$
 2d. Describe the quadrant Amp , and make $mc = 3$ points.
 3d. Through c draw AB , meeting DB , drawn through D , parallel to Ap .



COMPUTATION.

As cos. co. $= 33^{\circ} 45'$	0,08015	As cos. co. $= 33^{\circ} 45'$	0,08015
To diff. lat. $= 120 \text{ m.}$	2,07918	To diff. lat. $= 120 \text{ m.}$	2,07918
So rad. $= 90^{\circ} 00'$	10,00000	So sin. co. $= 33^{\circ} 45'$	9,74474
To dist. $= 144,3$	2,15933	To dep. $= 80,18$	1,90407

Answer { Ship has run 144,3 miles.
 And has got to the westward 80,18 miles.

QUEST. VI. Two ports lie under the same meridian, one in latitude $52^{\circ} 30' N.$ and the other in latitude $47^{\circ} 10' N.$ A ship from the southernmost sails due east 9 knots an hour, and two days after meets a sloop that had sailed from the northernmost port: Required the sloop's direct course and distance run?

Here the distance which the ship sails east is the sloop's departure.

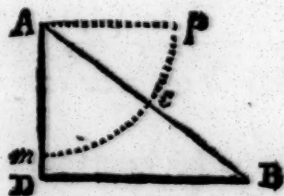
Now 2 days $= 48$ hours.

Then $48 \times 9 = 432 \text{ m.} = \text{departure.}$

Sloop's lat. $52^{\circ} 30' N.$

Ship's lat. $47^{\circ} 10' N.$

Diff. lat. $5^{\circ} 20' = 320 \text{ m.}$



CONST. In the meridian, take AD for the diff. lat. 320 m. and perpendicular to AD draw the departure $DB = 432 \text{ m.}$ and draw the distance AB .

COMPUTATION.

As diff. lat. $= 320 \text{ m.}$	7,49485	As sin. co. $= 53^{\circ} 28'$	0,09501
To depart. $= 432 \text{ m.}$	2,63548	To depart. $= 432 \text{ m.}$	2,63548
So rad. $= 90^{\circ} 00'$	10,00000	So rad. $= 90^{\circ} 00'$	10,00000
To tan. co. $= 53^{\circ} 28'$	10,13033	To dist. $= 537,6$	2,73049

Answer { The sloop has sailed S. $53^{\circ} 28' E.$ or SE. $\frac{1}{4} E.$
 And has run 537,6 miles.

C 2

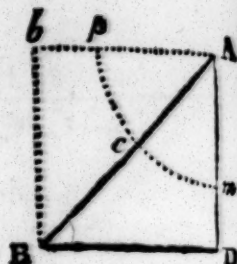
QUEST.

QUEST. VII. *A ship from a port in latitude $38^{\circ} 25'$ S. sails between the S. and W. at the rate of $7\frac{1}{2}$ knots an hour; three days after meets a sloop, who two days before had sailed from a port under the same meridian which the ship departed from, and kept on a west course 8 miles an hour: Required the ship's direct course and present latitude?*

Now 3 days is 72 hours, which, at $7\frac{1}{2}$ knots an hour, makes 540 miles for the ship's run.

And 2 days is 48 hours, which, at 8 knots an hour, makes 384 miles for the sloop's run, and is equal to the westing, or departure of the ship.

CONST. Having described the quadrant Amp , make $Ab=384$; from A , with 540, cut bB parallel to AD , in B ; draw AB , and BD parallel to Ap .



COMPUTATION.

As dist.	= 540 m.	7,26761	As rad.	= $90^{\circ} 00'$	10,00000
To rad.	= $90^{\circ} 00'$	10,00000	To dist.	= 540 m.	2,73239
So depart.	= 384 m.	2,58433	So cos. co.	= $45^{\circ} 20'$	9,84694
To fine co.	= $45^{\circ} 20'$	9,85194	To diff. lat.	= 379,6	2,57933

6,0)38,0(6° 20'

And $(38^{\circ} 25' + 6^{\circ} 20') = 44^{\circ} 45'$ S. Answer { Course S. $45^{\circ} 20'$ W. or SW.
Present latitude is $44^{\circ} 45'$ S.

QUEST. VIII. *A brig from a port in latitude $28^{\circ} 38'$ N. sails due N. at the rate of $8\frac{1}{2}$ knots an hour; after three days she meets a ship who had run due W. 342 miles from a port 30 leagues to the eastward of the meridian that the brig's crew thought themselves under; who also found, they had not increased their latitude so much by 24 leagues as by their account: Required the true course and distance the brig has made?*

Now $8\frac{1}{2}$ knots an hour for 3 days, is 612 miles for the brig's apparent northing; from which taking 24 leagues, or 72 m. her error in account, there remain 540 miles for her true diff. lat.

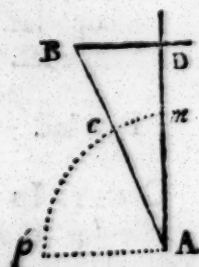
And as the ship's departed meridian is 30 leagues, or 90 miles to the eastward of the brig's; these 90 m. being taken from 342, leave 252 m. for the westing from the brig's meridian.

So that the brig having made 540 m. northing, and 252 m. westing; her course and distance, found by the 6th case (33), will be

Course N. $25^{\circ} 01'$ W. or NNW. $\frac{1}{4}$ W. nearly.

Distance 595,9 miles.

It may be proper to observe, that when radius is one of the three terms given, and not the first; then the log. of the first term being subtracted from the log. of the other term (radius excluded), leave the log. of the 4th term; by which means the trouble of taking the arith. comp. of the 1st term is avoided.



SECTION

SECTION V.

Of Compound Courses.

35. A COMPOUND COURSE is an irregular track which a ship makes in a known time, by sailing on several different courses: Or where two or more cases of Plane Sailing are concerned.

A TRAVERSE is a compound course, wherein several different successive courses and distances are known.

36.

TO WORK A TRAVERSE,

Or, to reduce a compound course to a single one.

1st. Make a table of six columns, title them Course, Distance, N. S. E. W. Begin at the left side, and write the given courses and distances in their respective columns.

2d. Seek in the traverse table the given courses and distances, and let the corresponding differences of latitude and departures be written in their proper columns in the table made for the question.

3d. Add up the columns of northing, southing, easting, and westing; then the difference between the sums of the northing and southing will be the whole difference of latitude, of the same name with the greater: and the difference between the sums of the easting and westing will be the whole departure, of the same name with the greater also.

4th. The whole diff. of lat. and departure to the compound course being found, the direct course and distance will be found as in Case VI. of single courses.

37.

TO CONSTRUCT A TRAVERSE.

1st. Describe a circle with the chord of 60 degrees, and divide it into 4 quadrants; marking the north point with N.

2d. Lay off each course on the circumference, reckoned from its proper meridian; and from the center to each point draw so many blank radii; mark these with the proper number of the course.

3d. On the first radius, lay the first distance, mark its extremity; through this extremity, and parallel to the second radius, draw the second distance of its proper length; through the extremity of the second distance, and parallel to the third radius, draw the third distance of its proper length: and thus proceed until all the distances are drawn.

4th. A line drawn from the extremity of the last distance, to the center of the circle, will represent the distance made good; and a line drawn from the same point, perpendicular to the meridian (lengthened if necessary) will represent the departure.

38. When a ship is bound from a given place to a known port; and on some occasion is obliged to run on one or more different courses, not in the direct one to the port; and then wants to find the direct course and distance she must run to gain her port, observe the following precepts.

1st. Find the diff. lat. and dep. between the ship's first place and the port bound to.

2d. Find the diff. lat. and dep. between the ship's first place and the place she is to come to.

3d. If these differences of latitude are both of the same name, take their difference for a new diff. lat.: But if of contrary names, take their sum.

4th. If the departures are both of the same name, take their difference for a new departure: But take their sum, if of contrary names.

5th. To this new difference of latitude and departure, find the course and distance (33).

6th. If between the place sailed from, and the place come to, there has been more than one course: To each course let the diff. lat. and departure be found; and let their sum or difference be taken according as they are, of the same, or of contrary names; and this will give the diff. lat. and departure between the place sailed from, and the place come to: Then proceed by the 3d, 4th, and 5th precepts.

39. TO CONSTRUCT A COMPOUND COURSE.

See any of the figures after Question VII.

1st. Describe a circle, in which draw the meridian and parallel of the place sailed from.

2d. Construct the triangle between the place sailed from, marked A, and the place bound to, marked B; and let the intersection of the diff. lat. and departure be marked D.

3d. Construct the figure between the place sailed from, or A, and the place come to, marked C; and let the intersection of this diff. lat. and departure be marked E.

4th. Through C draw CF parallel to AD, meeting BD, continued, if necessary, in F; and draw CB.

5th. Then in the triangle CFB, the lines CF, FB, CB, will represent the diff. lat. departure, and distance between the place come to, and the place bound to.

6th. From the center A draw a line parallel to CB, in the direction from C to B, and this shews the course wanted.

40. *Examples to exercise Traverse Sailing.*

QUESTION I. *A ship sails from a place in latitude $24^{\circ} 32' N.$ and has run the following courses and distances, viz.*

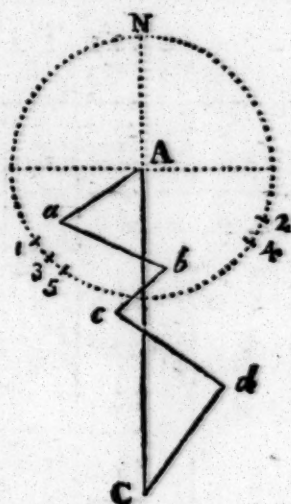
1st. SW. b. W. dist. 45 m. 2d ESE. dist 50 m. 3d. SW. dist. 30 m.

4th. SE. b. E. dist. 60 m. 5th. SW. b. S. $\frac{1}{4}$ W. dist. 63 m.

Required her present latitude, with the direct course and distance between the place sailed from, and the place come to?

Construct the traverse table by art. 36, and the figure by art. 37.

TRAVERSE TABLE.					
Courses.	D.	N.	S.	E.	W.
SW. b. W.	45		25,0		37,4
ESE.	50		19,1	46,2	
SW.	30		21,2		21,2
SE. b. E.	60		33,3	49,9	
SW. b. S. $\frac{1}{4}$ W.	63		50,6		37,5
			149,2	96,1	96,1



The traverse table being completed; the sum of the southings is 149,2 miles, and so far the ship has got to the southward, or altered her latitude.

The lat. from $24^{\circ} 32' N.$

Diff. lat. $\frac{149}{60} = 2 \ 29 \ S.$

Present lat. $22 \ 03 \ N.$

The miles of departure in the east column are 96,1; and those in the west column are also 96,1: But as the east and west departures are directly opposite, they destroy one another, and the ship in her present station has made no departure; therefore she is under the same meridian which she sailed from: Consequently her course made good is directly south; and her distance is the same as the difference of latitude, which is 149,2.

In this figure the circle, which is described with the chord of 60° , represents the horizon, the center of which is the place the ship sailed from; through that place are drawn two diameters, at right angles to one another; the one representing the meridian, the other the parallel of latitude which the ship departed from: On the circumference are laid the several courses, and numbered 1, 2, 3, 4, 5. On the first rhumb A 1, is laid the first distance $Aa = 45$; through a , and parallel to the rhumb A 2, is drawn the second distance $ab = 50$; through b , and parallel to the rhumb A 3, is drawn the third distance $bc = 30$; through c , and parallel to the rhumb A 4, is drawn the fourth distance $cd = 60$; through d , and parallel to the rhumb A 5, is drawn the 5th distance $dc = 63$.

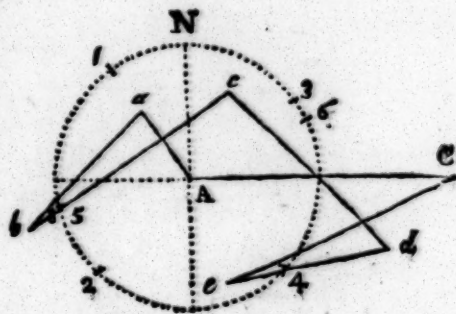
QUEST. II. *A ship from the latitude $28^{\circ} 32' N$. has run the following courses, viz.*

1st. NW. b. N. dist. 20 m. 2d. SW. dist. 40 m. 3d. NE. b. E. dist. 60 m.
4th. SE. dist. 55 m. 5th. W. b. S. dist. 41 m. 6th. ENE. dist. 66 m.

Required her present latitude, with the direct course and distance between the place sailed from and the place come to?

Construct the traverse table by art. 36, and the figure by art. 37.

TRAVERSE TABLE.					
Courses.	D.	N.	S.	E.	W.
NW. b. N.	20	16,6			11,1
SW.	40		28,3		28,3
NE. b. E.	60	33,3		49,9	
SE.	55		38,9	38,9	
W. b. S.	41		8,0		40,2
ENE.	66	25,3		61,0	
		75,2	75,2	149,8	79,6
				79,6	
				70,2	Dep.



The traverse table being filled up, the sum of the northings and southings are both 75,2 miles; which, being of contrary directions, shew that the ship has returned to the same parallel of latitude which she sailed from.

The sum of the eastings is 149,8, and that of the westings is 79,6; their difference 70,2 shews that the ship has gained so much to the eastward, that being greatest.

Consequently the course made good is due east.

And the distance is 70,2 miles.

Although the figures in both the traverse tables, at the end of this book, contain two decimal places, besides the whole numbers, yet only one decimal place is used in these traverse questions, and that place is increased by 1, if the place omitted exceeded 5: Thus, the course SW. dist. 40, gives 28,28; for which it is set down 28,3; because 28,28 is nearer to 28,30 than to 28,20: And so of others.

Here A is the place sailed from; and c is the place the ship is come to, by sailing along the lines Aa, ab, bc, cd, de, eC.

The distance she is got from A, is represented by A c; which also expresses the rhumb between A and c,

QUEST.

1ft. SW. b. S. 20 m. 2d. W. 16 m. 3d. NW. b. W. 28 m.
4th. SSE. 32 m. 5th. ENE. 14 m. 6th. SW. 36 m.

TRAVERSE TABLE.

As the courses steered by both ships are equally distant from the meridian; therefore one traverse will serve for both.

TRAVERSE TABLE.

QUEST.

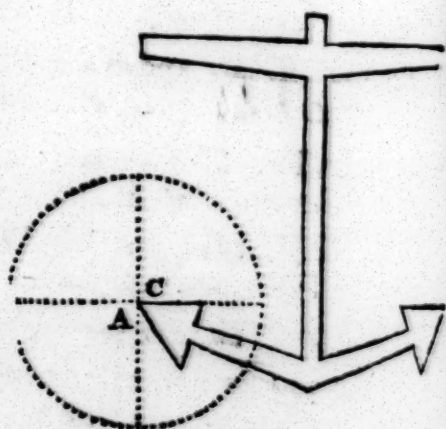
QUEST. V. Suppose a ship from the lat. of $40^{\circ} 00' N.$ sails as follows.

1st. SE. b. S.	29 m.	2d. NNE.	10 m.	3d. ESE.	
4th. ENE.	50 m.	5th. SSE.	10 m.	6th. NE. b. N	50 m.
7th. West	25 m.	8th. SSE.	10 m.	9th. WSW. $\frac{1}{2} W.$	29 m.
10th. North	110 m.	11th. E. $\frac{3}{4} N.$	62 m.	12th. North.	42 m.
13th. West	62 m.	14th. North	10 m.	15th. West	7 m.
16th. South	10 m.	17th. West	62 m.	18th. South	8 m.
19th. E $\frac{3}{4} S.$	62 m.	20th. South	110 m.	21st. WNW. $\frac{1}{2} W.$	7 m.
22d. NNE.	10 m.	23d. West	25 m.		42 m.

Required the ship's place, with the direct course and distance?

TRAVERSE TABLE.

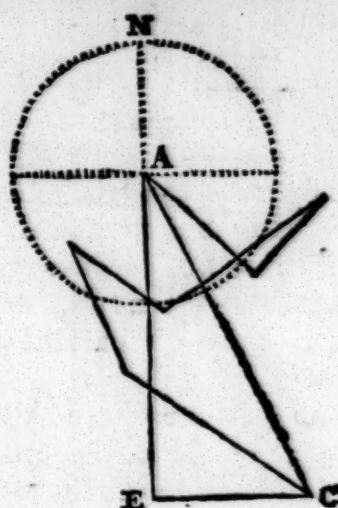
Courses.	D.	N.	S.	E.	W.
SE. b. S.	29		24,1	16,1	
NNE.	10	9,2		3,8	
ESE.	50		19,1	46,2	
ENE.	50	19,1		46,2	
SSE.	10		9,2	3,8	
NE. b. N.	29	24,1		16,1	
West.	25				25,0
SSE.	10		9,2	3,8	
WSW. $\frac{1}{2} W.$	42		12,2		40,2
North.	110	110,0			
E. $\frac{3}{4} N.$	62	9,1		61,3	
North.	7	7,0			
West.	62				62,0
North.	10	10,0			
West.	8				8,0
South.	10		10,0		
West.	62				62,0
South.	7		7,0		
E. $\frac{3}{4} S.$	62		9,1	61,3	
South.	110		110,0		
WNW. $\frac{1}{2} W.$	42	12,2			40,2
NNE.	10	9,2		3,8	
West.	25				25,0
		209,9	209,9	262,4	262,4



As the sums of the North and South difference of latitudes are equal, and the East and West departures are equal; therefore the ship is returned to the place she sailed from.

QUEST. VI. The last 24 hours we have run the following courses, viz.
 1st. SE. 40 m. 2d NE. 28 m. 3d. SW. b. W. 52 m.
 4th. NW. b. W. 30 m. 5th. SSE. 36 m. 6th. SE. b. E. 58 m.
 Required the diff. latitude, departure, direct course, and distance?

TRAVERSE TABLE					
Courses.	D	N.	S.	E.	W.
SE.	40		28,3	28,3	
NE.	28	19,8		19,8	
SW. b. W.	52		28,9		43,2
NW b W.	30	16,7			24,9
SSE.	36		33,3	13,8	
SE b. E.	58		32,2	48,2	
		36,5	122,7	110,1	68,1
			36,5	68,1	
		D. lat.	86,2	42,0	Dep..

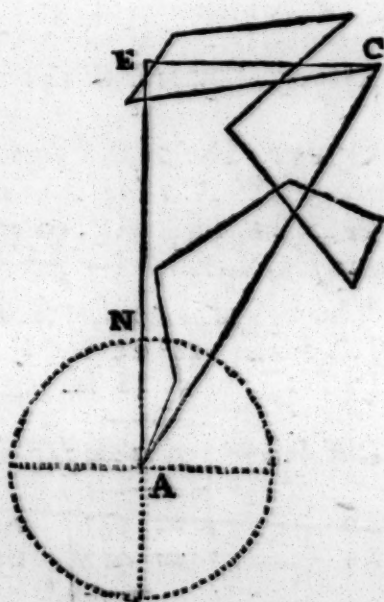


For the course. As 86,2 m. : 42 m. :: rad. : t. $25^{\circ} 59'$. Or SSE. $\frac{1}{4}$ E. nearly.
 For the distance. As f. $25^{\circ} 59'$: 42 m. :: rad. : 95,87 m.

QUEST. VII. Yesterday noon we were in lat. $3^{\circ} 18'$ S. and since then we have plied on the following courses, viz.

1st. NNE. 22 m. 2d. N. b. W. 30 m. 3d. NE. b. E. 40 m.
 4th. ESE. 25 m. 5th. SSW. 18 m. 6th. NW. b. N. $\frac{1}{2}$ W. 50 m.
 7th. NE. $\frac{1}{2}$ E. 42 m. 8th. W. b. S. $\frac{1}{2}$ W. 45 m. 9th. SW. b. S. 20 m.
 10th. E. b. N. $\frac{1}{4}$ E. 62 m. Required our present lat. and departure with the course and distance made good?

TRAVERSE TABLE.					
Courses	D.	N.	S.	E.	W.
NNE	22	20,3		8,4	
N. b. W.	30	29,4			5,8
NE. b. E.	40	22,2		33,3	
ESE.	25		9,6	23,1	
SSW.	18		16,6		6,8
NW. b. N. $\frac{1}{2}$ W.	50	38,6			31,7
NE. $\frac{1}{2}$ E.	42	26,6		32,5	
W. b. S. $\frac{1}{2}$ W.	45		4,4		44,8
SW. b. S.	20		16,6		11,1
E. b. N. $\frac{1}{4}$ E.	62	9,1		61,3	
		146,2	47,2	158,6	100,2
			47,2	100,2	
		99,0	D. lat.	58,4	Dep.

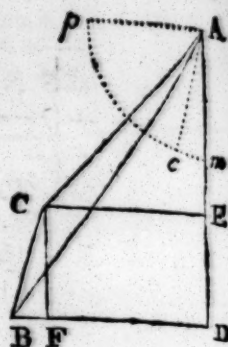


For the course. As 99 m. : 58,4 m. :: rad. : t. $30^{\circ} 32'$. Or NNE. $\frac{1}{4}$ E.
 For the dist. As f. $30^{\circ} 32'$: 58,4 m. :: rad. : 115, the distance.
 And $3^{\circ} 18' - 1^{\circ} 39' = 1^{\circ} 39'$ S. the present latitude.

QUEST.

QUEST. VIII. Yesterday noon we were in lat. $33^{\circ} 15' N.$ and bound to a port in lat. $28^{\circ} 35' N.$ lying 196 miles to the west; and this day at noon we were in lat. $30^{\circ} 20' N.$ having made 168 miles of westing: Required the direct course and distance to our intended port?

Lat. from $33^{\circ} 15' N.$	Lat. from $33^{\circ} 15' N.$
Lat. to $28^{\circ} 35' N.$	Lat. in $30^{\circ} 20' N.$
Diff. lat. $4^{\circ} 40' = 280 m.$	Diff. lat. $2^{\circ} 55' = 175$



The figure is constructed by art. 39.

Thus. In the meridian take $AD = 280$, $AE = 175$; in DB , EC , drawn parallel to the parallel of lat. AP , take $BD = 196$, $EC = 168$; draw AB , AC , CB ; and draw CF parallel to AD , and Ac parallel to CB .

Then A is the place sailed from; c the place come to; B the place bound to; CB the distance the ship has to sail; and the arc mc measures the angle of the course she must sail on.

From AD	$= 280$	From DB	$= 196$
Take AE	$= 175$	Take $CE = FD$	$= 168$
Leaves $ED = CF$	$= 105$	Leaves BF	$= 28$

In the triangle CFB .

To find the course.			To find the distance.		
As CF , diff. lat.	$= 105$	7,97881	As fin. co.	$= 14^{\circ} 56'$	0,58889
To BF , dep.	$= 28$	1,44715	To dep.	$= 28 m.$	1,44716
So rad.	$= 90^{\circ} 00'$	10,00000	So rad.	$= 90^{\circ} 00'$	10,00000
Tot. $\angle BCF$, t.co. $= 14^{\circ} 56'$		9,42596	To dist.	$= 108,6$	2,03605

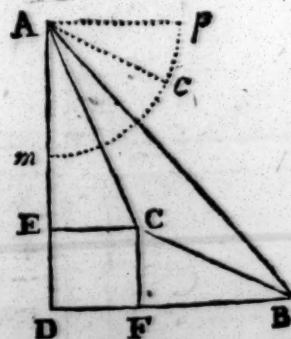
Answer: Course is $S. 14^{\circ} 56' W.$ or $S. b. W. \frac{1}{4} W.$ Dist. 108,6 miles.

QUEST. IX. A ship from latitude $14^{\circ} 25' N.$ and bound to a port in latitude $5^{\circ} 18' N.$ lying 476 miles to the eastward, finds she has made 400 miles of southing, and 150 of easting: Required the course and distance she has to sail, to reach her intended port?

The figure is constructed by art. 39.

Lat. from $14^{\circ} 25' N.$
Lat. to $5^{\circ} 18' N.$
Diff. lat. $9^{\circ} 7' = 547 miles.$

AD	$= 547$	DB	$= 476$
AE	$= 400$	$EC = DF$	$= 150$
$ED = CF$	$= 147$	FB	$= 326$



Then $CF : FB :: \text{rad.} : t. \angle BCF$. Or $147 : 326 :: t. 45^{\circ} : t. 65^{\circ} 44'$.
And $f. \angle FCB : FB :: \text{rad.} : CB$. Or $f. 65^{\circ} 44' : 326 :: f. 90^{\circ} : 357,6$.
Answer, Course is $S. 65^{\circ} 44' E.$; or $SE. b. E. \frac{1}{4} E.$ Distance 357,6 m.

QUEST. X. Four days ago we were in lat. $4^{\circ} 39'$ S. long. $83^{\circ} 16'$ E. of London; and now we are in lat. $0^{\circ} 35'$ N. having made 200 miles of westing: Required our present course and distance to Achen in the Island of Sumatra?

The fig. is constructed by art. 39.

Lat. from $4^{\circ} 39'$ S.
Lat. to $5 \quad 15$ N.

Diff. lat. $9 \quad 54 = 594$ miles.

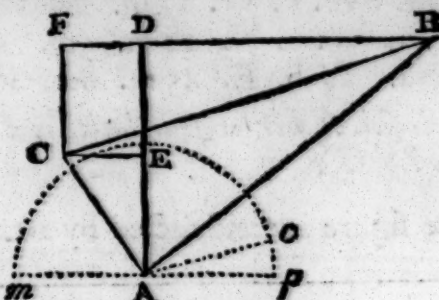
Lat. from $4^{\circ} 39'$ S.
Lat. in $0 \quad 35$ N.

Diff. lat. $5 \quad 14 = 314$ miles.

$$AD = 594$$

$$AE = 314$$

$$ED = 280 = CF.$$



Long. from $83^{\circ} 16'$ E.
Long. to $95 \quad 55$ E.

Diff. long. $12 \quad 39 = 759$ miles.

$$DB = 759$$

$$FD = 200 = CE$$

$$FB = 959$$

In the triangle CFB, to find the course and distance.

As CF : FB :: rad. : t. $\angle FCB$. Or $280 : 959 :: t. 45^{\circ} 00' : t. 73^{\circ} 43'$.
As f. $\angle FCB$: FB :: rad. : CB. Or f. $73^{\circ} 43' : 959 :: f. 50^{\circ} 00' : 999$.

Answer { The course is N. $73^{\circ} 43'$ E. or ENE. $\frac{1}{2}$ E.
The distance is 999 miles.

QUEST. XI. A ship from the lat. $10^{\circ} 38'$ N. and bound to a port lying 282 miles to the S. W. b. S. after three successive days of bad weather, finds herself in lat. $3^{\circ} 58'$ N. and 120 miles to the eastward: Required her present course and distance to her intended port?

The figure is constructed by art. 39.

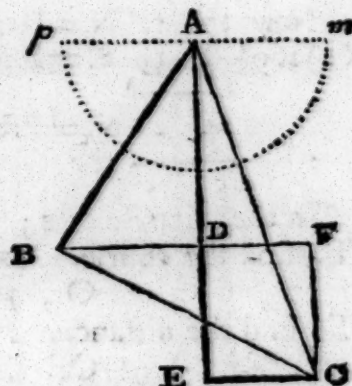
In the triangles ABD, find AD and BD.

As rad. : AB :: f. $\angle B$: AD.

Or rad. : 282 :: f. $56^{\circ} 15'$: 234,5.

And rad. : AB :: f. $\angle BAD$: BD.

Or rad. : 282 :: f. $33^{\circ} 45'$: 156,6.



Lat. from $10^{\circ} 38'$ N.

$$AE = 400$$

$$BD = 156,6$$

Lat. in $3 \quad 58$ N.

$$AD = 234,5$$

$$EC = DF = 120$$

Diff. lat. $6 \quad 40 = 400$ m. $DE = CF = 165,5$

$$BF = 276,6$$

In the triangle CFB find the course and distance.

As CF : FB :: rad. : t. $\angle FCB$. Or $165,5 : 276,6 :: rad. : t. 59^{\circ} 6'$.

As f. $\angle FCB$: FB :: rad. : CB. Or f. $59^{\circ} 6' : 276,6 :: rad. : 322,4$.

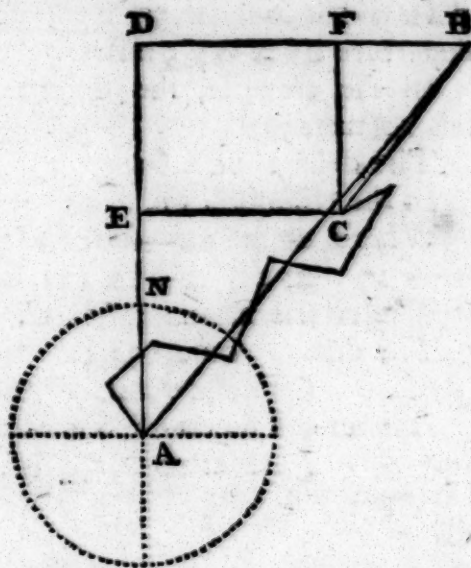
Answer { Course is N. $59^{\circ} 6'$ W. Or NW. b. W. $\frac{1}{4}$ W.
Distance is 322,4 miles.

QUEST.

NW. 25 m. NE. b. E. 28 m. E. b. S. $\frac{1}{4}$ E. 32 m. NNE. 41 m.
ESE. $\frac{1}{2}$ E. 24 m. NE. b. N. 39 m. WSW. 24 m.

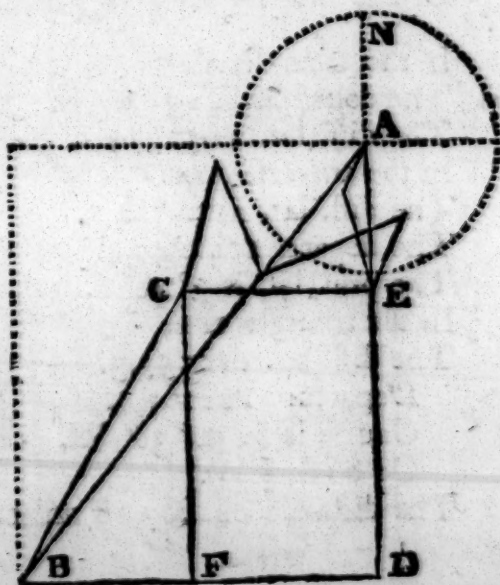
The diff. lat. AD $\approx$ 150 m.

In the triangle CFB, where CF = 67,4; FB = 47,5; the course is N. $35^{\circ} 14'$ E. or NE. b. N. $\frac{1}{4}$ E.; and the distance is 82,51 miles.



SSW. 22 m. S. b. E. $\frac{1}{2}$ E. 38 m. NNE. 30 m. WSW. 57 m.
NNW. 45 m. S. b. W. $\frac{1}{2}$ W. 50 m.

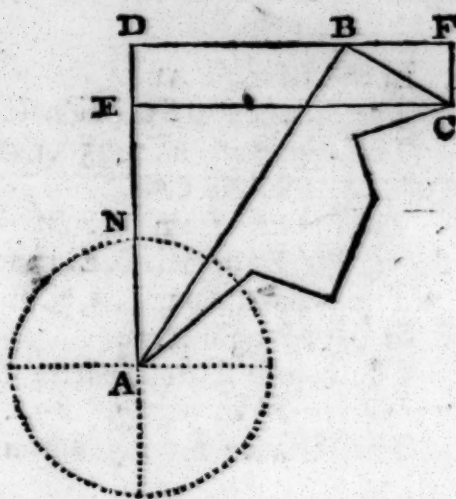
Latit. in



QUEST.

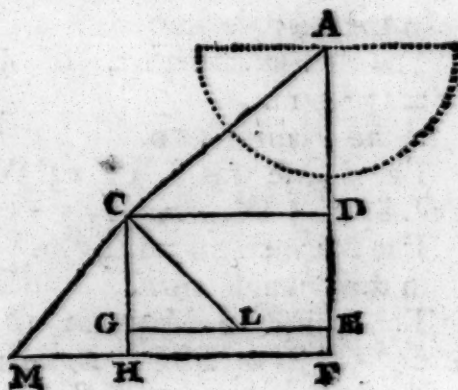
QUEST. XVII. A ship from the latitude of $4^{\circ} 10' N.$ being to make an Island that bears NE. b. N. distant 196 miles, and having run these courses, viz. NE. $\frac{1}{2}$ E. 75 m. ESE. $\frac{1}{4}$ E. 42 m. NNE. $\frac{1}{4}$ E. 52 m. N. b. W. 34 m. ENE. $\frac{1}{2}$ E. 49 m. It is desired to know her present latitude, with her direct course and distance to the Island?

In the triangle ADB.
The diff. lat. $AD=163$.
The depart. $BD=108,9$.
In the traverse AEC.
The diff. lat. $AE=128$.
The depart. $EC=160$.
And the present lat. $6^{\circ} 18' N.$
In the triangle CFB.
The diff. lat. $CF=35$.
The depart. $FB=51,1$.
The course is N. $55^{\circ} 36' W.$
Or NW. b. W. nearly.
The distance $CB=61,93$ miles.



QUEST. XVIII. Two ships take their departure from the Lizard in latitude $49^{\circ} 57' N.$; one bound to St. Michael's which lies 715 m. to the S. and 745 m. to the west; the other bound to Lisbon, lying 661 m. to the S. and 215 m. to the west, reckoning from the Lizard; they sail in company SW. $\frac{1}{2}$ W. 610 miles, and then part: What is the direct course and distance of each ship to her port?

In the triangle ADC.
The diff. lat. $AD=387$ m.
The depart. $DC=471,5$ m.
In the triangle CGL.
The course is S. $43^{\circ} 07' E.$
Or SE. b. S. $\frac{1}{4}$ E. nearly.
The distance $CL=375,3$ m.
In the triangle CHM.
The course is S. $39^{\circ} 49' W.$
Or SW. b. S. $\frac{1}{2}$ W. nearly.
The distance $CM=427,1$ m.



QUEST. XIX. A ship in lat. $43^{\circ} 20' N$. long. $15^{\circ} 10' W$. is bound to St. Michael's, bearing S. $46^{\circ} 16' W$. in the lat. $37^{\circ} 45' N$; and from thence she is bound to Madeira, in lat. $32^{\circ} 25' N$. and distant from St. Michael's 514 m. in the SE. quarter: Required the distance to St. Michael's, the course from thence to Madeira, together with the course and distance from Madeira to the Island of Palma, in lat. $28^{\circ} 36' N$. long. $18^{\circ} 00' W$.

In the triangle ABC.

The distance to St. Michael's, $AC = 484,6$ m.

The departure $BC = 350,1$ m.

In the triangle CED.

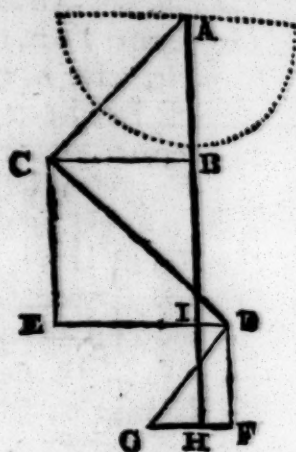
The course from St. Michael's to Madeira is S. $51^{\circ} 30' E$. or SE. $\frac{1}{2} E$. nearly.

The depart. $ED = 402,3$ m.

In the triangle DFG.

The course from Madeira to Palma is S. $44^{\circ} 07' W$. or SW. nearly.

The distance $DG = 318,9$ m.



QUEST. XX. Departing from St. Mary's, one of the Azores, and bound to the river Sierra Leon, after running SE. 36 hours, at 7 knots an hour, my sea compass was spoiled by a flash of lightning; then after 8 days direct run between the S. and W. I met a ship in lat. $20^{\circ} 00' N$. long. $36^{\circ} 10' W$. and bound to Mayo, one of the Cape Verd Isles, to which I sailed in her company: Required my course and distance in the 8 days run; also the same, while I sailed in company; and the same, from Mayo to Sierra Leon.

In the triangle ABC.

The diff. lat. = depart. or $AB = BC = 178,2$ m.

In the triangle CFD.

The course was S. $43^{\circ} 13' W$. or SW. b. S. $\frac{1}{4} W$. nearly.

The distance $CD = 1195$ m.

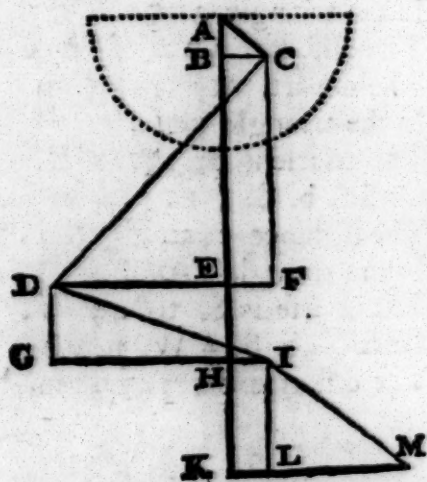
In the triangle DGI.

The course to Mayo at I, was S. $69^{\circ} 56' E$. or ESE. $\frac{1}{4} E$. nearly.

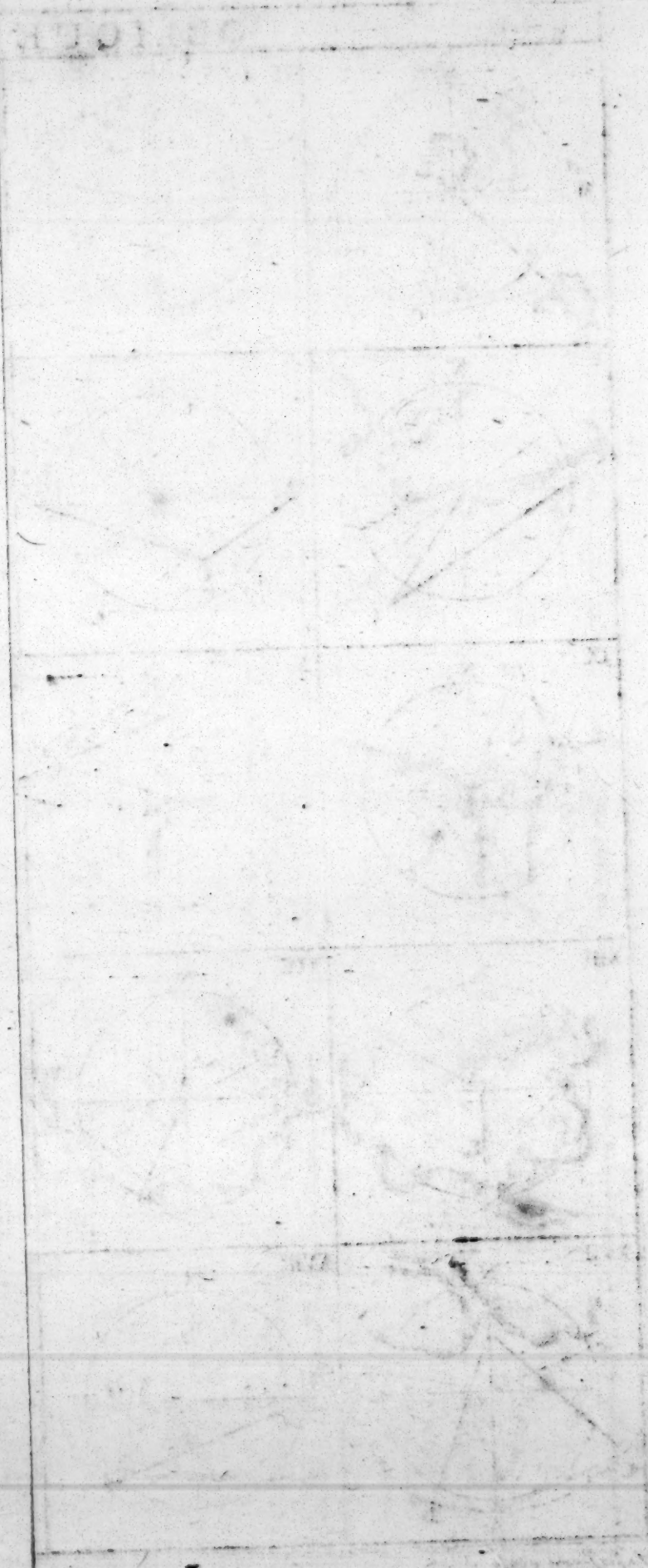
The distance $DI = 836,8$ m.

In the triangle ILM.

The course to Sierra Leon at M was S. $58^{\circ} 29' E$. or SE. b. E. $\frac{1}{4} E$. nearly; and the dist. $IM = 770,7$ m.



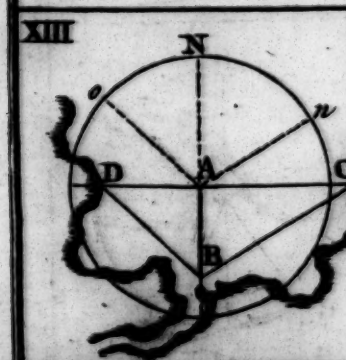
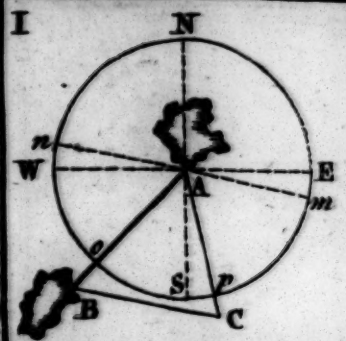
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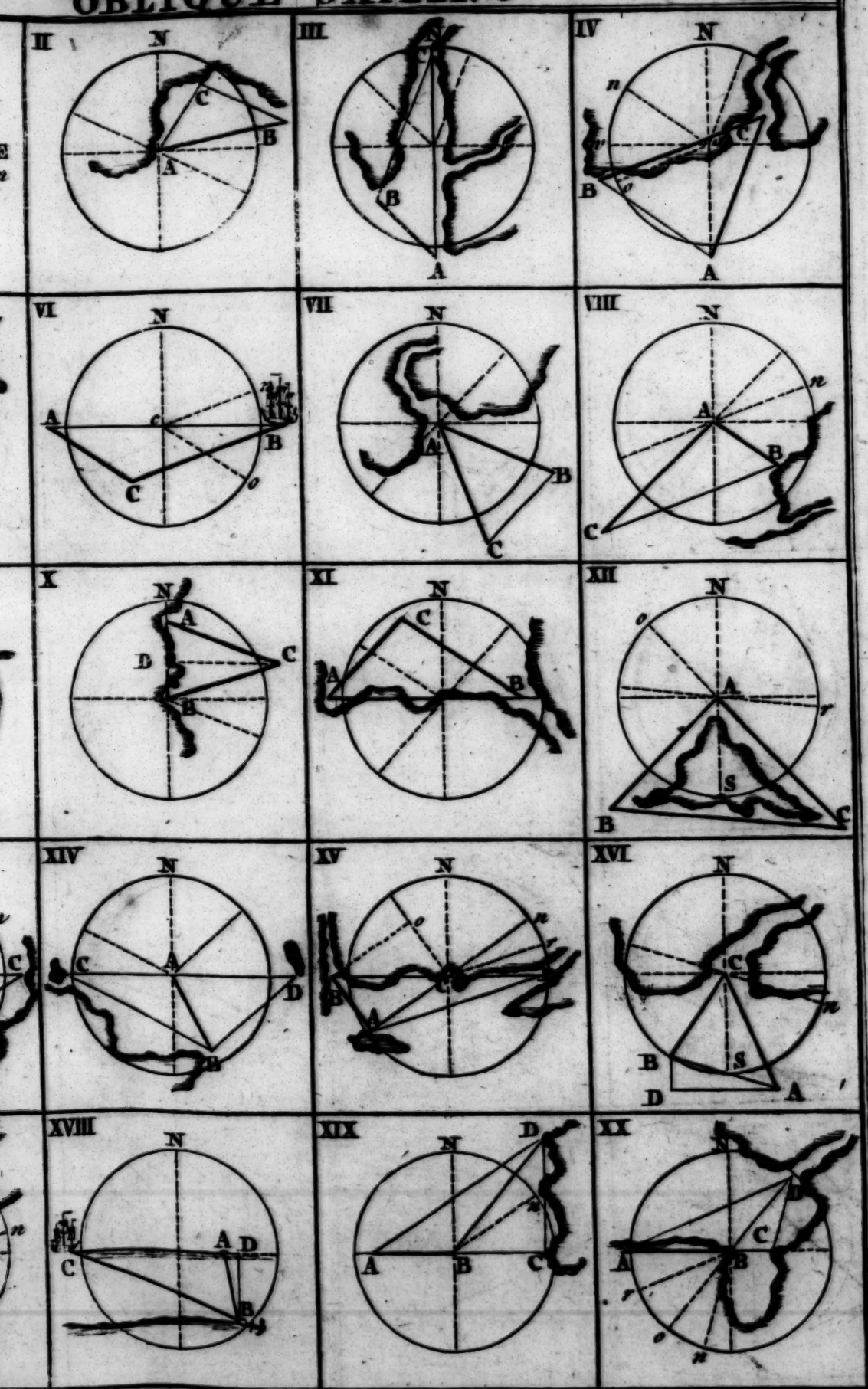
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J. Jefferys sculp.

OBLIQUE SAILING

Pl. VIII.



SECTION VI.

Of oblique Sailing.

41.

In the preceding sections the bearing and distances of places were determined by the solution of right-angled triangles; but at sea there being many cases in which only oblique positions can be observed, therefore it is necessary to shew how such cases are to be solved; which will be amply illustrated in this, and some of the following sections.

To set an object is to observe what rhumb or point of the nautical compass is directed to it.

The bearing of an object is the rhumb on which it is seen; and the bearing of one place from another, is reckoned by the name of the rhumb passing through those two places.

In every figure relating to any case of plane sailing the bearing of a line, not running from the center of the circle or horizon, is found by drawing a line parallel thereto, from the center, and toward the same quarter.

The figures belonging to the questions in this section are in Plate VIII: at the end, in which the figures are referred to by the number of the question.

QUEST. I. *Two ships, A and B, sail from two Islands bearing the one from the other NE. and SW. their distance being 76 miles; A sails S. b. E. and B runs E. b. S. at last they meet: How far has each sailed?*

CONSTRUCTION. With the chord of 60° describe a circle representing the horizon of one of the places sailed from, suppose of A, the northern; draw the meridian NS , and at right angles to it draw the parallel of latitude EW .

In this circle lay off the SW . rhumb so , the $S. b. E.$ rhumb sp , and the $E. b. S.$ sm : through o draw AB equal to 76 miles.

Through B draw BC parallel to Am , meeting Ac drawn through p .

Then A and B represent the places sailed from; AC and BC the distances, and the angles sAc and sAm the courses which the ships had sailed when they met at c .

The distances AC and BC may be measured on the scale which AB was taken from.

COMPUTATION. In the triangle ABC there is given one side AB , and all the angles, to find the other sides.

Thus, $\angle A = 5 \text{ pts.} = 56^\circ 15'$. For so and sp make 5 pts. meas. $\angle A$.

$\angle B = 5 \text{ pts.} = 56^\circ 15'$. For BC is paral. Am ; and $\angle B = \angle BAN$ (II. 95) = 5 pts.

$\angle C = 6 \text{ pts.} = 67^\circ 30'$. For BC is paral. Am ; and $\angle C = \angle CAM$ (II. 95) = 6 pts.

Therefore the solution belongs to Problem I. Book III. 45.

And $f. \angle C : AB :: f. \angle A : BC$. Or, $As f. 67^\circ 30' : 76 \text{ m.} :: f. 56^\circ 15' : 68,4 \text{ m.}$

Now as $\angle B = \angle A$: Therefore AC is equal to BC .

(II. 104)

ANSWER. $\left\{ \begin{array}{l} A \text{ sails } S. b. E. 68,4 \text{ miles.} \\ B \text{ sails } E. b. S. 68,4 \text{ miles.} \end{array} \right.$

D 2

QUESTION

QUESTION II. *Coasting along shore, a headland bore NE. b. N.; then having run E. b. N. 15 miles, the headland bore WNW.: Required the distance from the headland at each time of setting.*

The construction and computation of this question is made as in Quest. I.; c being the headland, and AB the ship's run.

ANSWER, the distance is $\begin{cases} 8,496 \text{ m. at first setting.} \\ 10,81 \text{ m. at second.} \end{cases}$

QUESTION III. *In doubling a cape, I observed a castle up a river bore due N.; then running NW. 6 miles, the castle bore NNE.: Required my distance from the castle at each time of setting.*

Here c is the castle, and AB the ship's run.

ANSWER, the castle's distance at $\begin{cases} \text{first is } AC = 14,48 \text{ m.} \\ \text{last is } BC = 11,08 \text{ m.} \end{cases}$

QUESTION IV. *At noon a headland bore NW. b. W.; then sailing NNE. 5 miles an hour, we anchored at 9 in the evening in a creek 18 leagues distant from the headland: Required its distance at noon, and bearing from the creek.*

CONSTRUCTION. Having described the horizon, and drawn the meridian and parallel, in the meridian take any point A for the ship's place at first: draw the NW. b. W. and NNE. rhumbs, and parallel to them draw AB, AC.

Make $AC = 45 \text{ m. } (= 9 \text{ h.} \times 5 \text{ m.})$: and from c with $54 \text{ m. } (= 18 \text{ l.} \times 3)$ cut AB in B. Then is B the headland, and c the creek.

COMPUTATION. Here is given the side $AC = 45 \text{ m.}$; the side $CB = 54 \text{ m.}$ and the $\angle A = 78^\circ.45 = 7 \text{ pts. for NW. b. W.} + 2 \text{ pts. for NNE.} = 7 \text{ points.}$

Therefore the solution falls under Problem I. Book III. 45.

And $\angle B = 54^\circ 49'$; therefore $\angle C = 46^\circ 26'$; and $AB = 39,9 \text{ miles.}$

Draw a o parallel to CB, then $\angle CBA = \angle oan = 54^\circ 49'$.

Therefore $\angle oan - \angle naw = \angle oaw = 21^\circ 04'$; which taken from 90° co' leaves $68^\circ 56'$.

ANSWER, the headland's $\begin{cases} \text{distance at noon is } 39,9 \text{ miles.} \\ \text{bearing from the creek is S. } 68^\circ 56' \text{ W. or} \\ \text{WSW. } \frac{1}{4} \text{ W. nearly.} \end{cases}$

QUESTION V. *A ship, after sailing SE. b. S. 62 leagues from her port in lat. $29^\circ 16' \text{ N.}$ met a sloop that had run 124 leagues from a place bearing W. b. N. of the port the ship departed from: What was the sloop's course, and the distance of the two ports?*

The construction and computation being made as in the last, A and B represent the ports sailed from; and c the place where the vessels met.

ANS. $\begin{cases} \text{The distance of the ports } 72,18 \text{ leagues.} \\ \text{The sloop's course along CB is S. } 58^\circ 03' \text{ E. or SE. b. E. } \frac{1}{4} \text{ E. nearly.} \end{cases}$

QUEST.

QUESTION VI. *A merchant ship meeting with a ship of war which had sailed SE. b. E. 39 leagues from the latitude of $45^{\circ} 30'$ N. informed them, that she had been plundered the day before in the same latitude; and had since run 67 leagues on a direct course between the south and west; and that the pirates were cruising about the place where they robbed her: What course must the man of war steer to come up with them?*

Suppose A the place the man of war sailed from, B the place where the merchantman was robbed, C the place where they met; then the man of war must sail along CB to meet the pirates; which course will be shewn by cn drawn parallel to CB.

Here the given distance AC is not drawn from the center of the circle representing the horizon, but parallel to co the given course; this was done, to prevent the figure from being so small as it must otherwise have been.

Here are two given sides and an angle opposite to one of them, to find the angle B opposite to the other side AC.

Then $CB : \sin \angle A :: AC : \sin \angle B$. That is, As 67 l. : $\sin 33^{\circ} 45'$:: 39 l. : $\sin 18^{\circ} 52'$.

ANSWER. The course which the man of war must steer is $N. 71^{\circ} 08' E.$

For $\angle nCB = \angle C B c$ (II. 95); and $90^{\circ} - \angle nCB = \angle N c n$.

QUESTION VII. *Two ships sail at the same time from one port; one sails ESE. and the other SSE.: Required their bearing and distance when each has run $37\frac{1}{2}$ miles.*

Here $AB = AC$; therefore $\angle B = \angle C$. Now $\angle A = 4$ points; then $\angle C = \angle B = 6$ points.

ANSWER. B bears from C, $N. 45^{\circ} E.$ distant 28,7 miles.

QUESTION VIII. *Sailing on a SW. course at the rate of $4\frac{1}{2}$ miles an hour, at 9 o'clock in the forenoon a cape bore SE. b. E, distant 15 miles: Required its bearing and distance at 4 o'clock in the afternoon.*

ANSWER. The cape B bears $N. 68^{\circ} 08' E.$ distant 37,44 miles.

Here the ship is at A at 9 o'clock, and at C at 4 o'clock: the two sides AC, AB, and the contained angle $A = 9$ points, are given, to find the rest.

QUESTION IX. *Wanting to know the breadth of a river in the mouth of which are several islands; from a cliff on the eastern side, I sailed NNW. 50 miles; and then running SSW. 35 miles, I reached the western shore: Required the breadth between those places:*

Here $AB = 50$ m. $BC = 35$ m. and $\angle B = 4$ points; required AC.

ANSWER. The breadth between A and C is 35,35 miles.

QUESTION X. *From two ports, lying under the same meridian, and distant 236 miles, two ships sail toward the east, and meet when each has run 372 miles; Required the course of each.*

In Fig. X. A and B are the ports sailed from, and C the place where the ships met. Here are given the three sides; but two of them being equal, the solution is easily found by drawing the perpendicular CD.

ANSWER. A's course is S. $71^{\circ} 30' E.$ and B's course N. $71^{\circ} 30' E.$ (III. 49)

QUESTION XI. *Two ships meeting at sea, find they had sailed from two ports in the same latitude, and distant 576 miles: the ship from the western port had run between the N. and E. 328 miles, and the other had sailed 416 miles: Required the course steered by each ship.*

A and B are the ports sailed from, and C the place where the ships met. From the three given sides, the angles may be found by B. III. 49 or 50.

ANSWER. The course from A is N. $44^{\circ} 49' E.$ and from B is N. $55^{\circ} 59' W.$

QUESTION XII. *A sloop in three days coasted round a triangular-shaped island: the first day she ranged along one side, and her courses reduced to one was SW. distance 64 miles; the second day's distance was 106 miles between the S. and E.; and that of the third day was 83 miles: Required the direct courses of the second and third days.*

In Fig. XII. The first day's distance is AB, the second BC, the third AC. And the figure is thus constructed.

Having described the horizon, and drawn the meridian and parallel (22), their intersection A is taken for the place which the ship sailed from; draw the SW. rhumb $AB = 64$ miles; from A and B describe arcs with the radii 106 and 83; to their intersection C, draw the lines BC, AC.

Draw the line Ar parallel to BC, and continue CA to o.

Then the arc sr measures or gives the second day's course.

And the arc No the course of the third day.

Now the angles being found by either method, as in Book III. 62.; the courses will be thus obtained.

From $\angle BAC$ take 4 points $= \angle SAB$, there remains $\angle SAC$.

Then arc sr, or $\angle SAR = \angle SAC + \angle C (= \angle CAR$ by II. 95) for the second course.

And arc No, or $\angle NAo = \angle SAC$ (II. 93) is the third day's course.

ANSWER. The second day's course is S. $83^{\circ} 29' E.$ and the third day's N. $46^{\circ} 21' W.$

The directions given for this 12th question may be applied to the two preceding ones.

QUEST.

QUESTION XIII. *Sailing into a harbour I observed two landmarks, the one bore E. the other W.; and after running S. 3,3 miles, the eastern one bore N. $58^{\circ} 30'$ E. and the western one N. $47^{\circ} 20'$ W.: Required my distance from those landmarks at each time of setting them.*

The ship is supposed first at A, and to see the landmarks c and d in the lines AC, AD; then sailing to B, she sees the same marks in the lines BC, BD, drawn parallel to the given rhumbs An, Ao.

Here are two right angled triangles BAC, BAD to work in; there being known in each, the side AB, and all the angles; whence the solution will be as in Book III. 45.

ANSWER. $AD=3,58$ m. $AC=5,385$ m. $BD=4,87$ m. $BC=6,316$ m.

QUESTION XIV. *Coasting along shore I observed two islands, the one bore E. and the other W.; then sailing SSE. $\frac{1}{2}$ E. $16\frac{1}{2}$ miles, the western island bore NW. b. W. $\frac{1}{2}$ W. and the eastern bore NE. $\frac{1}{2}$ E.: Required their distance at each time of setting them.*

Here are two oblique angled triangles to work in; and the solution will be as in Book III. 54; there being one side AB and all the angles known.

ANSWER. $AC=19,45$ m. $AD=25,51$ m. $BC=30,88$ m. $BD=22,94$ m.

QUESTION XV. *Three ships, B, C, D, sail from the same road A, and bound to different ports lying in the same parallel of latitude; B's course is NW. b. N. distance 12 miles; C's course NE. b. E.; and D's course is ENE. $\frac{1}{2}$ E.: Required the distance of C and D from their ports, and also the distance of those ports from one another.*

Having described the horizon, and drawn the meridian and parallel, let their intersection c represent c's port, draw the given rhumbs co, cn, cr: make co=12 miles; produce nc towards A, and parallel to nA draw oB, meeting the west line in B; draw BA parallel to oc, and draw AD parallel to cr, meeting the east line in D: then A is the port sailed from, and B, C, D, are the ports bound to.

The solutions of these triangles are the same as in Book III. 54; there being given one side and all the angles.

Thus $\angle BAC=8$ points, $\angle B=5$ points, $\angle BCA=3$ points.

The $\angle BAD=9\frac{1}{2}$ points, $\angle D=1\frac{1}{2}$ point.

ANSWER. $AC=17,96$ m. $AD=34,36$ m. $BC=21,6$ m. $BD=39,56$ m.

QUESTION XVI. *Two ships, A and B, sail from the port C; A sails SSE. 50 miles, and B SW. b. S. 40 miles: Required their bearing and distance; and how far A is to the southward and eastward of B.*

Describe the horizon, draw the meridian and parallel, and their intersection c represents the port sailed from.

Draw the given rhumbs, in which take $CA=50$, $CB=40$: then A and B represent the places to which the ships are come.

Draw AB; and through B draw the meridian BD, meeting the parallel AD drawn through A: then BD is the difference of latitude, DA the departure, and BA shews the bearing and distance sought.

In the triangle CBA, find the unknown angles, and side BA by art. 60. Book III.

Draw $c n$ parallel to BA; then $\angle sca + \angle cas (= \angle acn$ (II. 95)) gives $\angle scn$ the bearing from B to A: and $\angle scn$ taken from 90° leaves $\angle BAD$: hence BD, DA, are found by art. 52. Book III.

ANSWER. $BA=43,33$ miles, $BD=12,93$ miles, $DA=41,36$ miles.
And the bearing from B to A is S. $72^\circ 38'$ E.

QUESTION XVII. *At sun-rise, being four o'clock, a ship saw a sloop to the WNW. and a brig to the E. b. N.; they all came to anchor along-side one another at nine o'clock, each having run since sun-rise five knots an hour, and the ship's course was due north: Required the courses sailed by the sloop and brig, and their distance from the ship in the morning when she set them.*

Draw the WNW. and E. b. N. rhumbs ao , an ; assume any point D in the meridian line for their anchoring place, and in the same line take $DA=25$ miles—the distance each sailed; through A draw AC, AB, parallel to ao , an , and on D with the radius DA describe a circle cutting AC, AB, in C, B: then A is the ship's place, c the sloop's, and B the brig's, at four in the morning.

Now $\angle C = \angle DAC = \angle D ao = 6$ points; therefore $\angle ADC = 4$ points.

And $\angle B = \angle DAB = \angle D an = 7$ points; therefore $\angle ADB = 2$ points.

The sides AC, AB, will be found by art. 56. Book III.

ANSWER. $\begin{cases} CA=19,13 \text{ miles, and c's course is NE.} \\ BA=9,755 \text{ miles, and B's course is NNW.} \end{cases}$

QUESTION XVIII. *Having dropped anchor in a very deep water, in a river, with a buoy and rope of 50 fathoms fixed to it, I fell down the stream till I had veered out 140 fathoms of cable, and then the buoy was 120 fathoms a-head of me: Required the depth of water.*

Construct the triangle ABC with the three given sides, letting $CA=120$ be horizontal to represent the surface of the water.

Draw

Draw BD perpendicular to CA continued; then B represents the anchor, A the buoy, C the ship, and BD the depth of the water.

In the triangle ABC find (III. 50) the angle ACB; then in the right angled triangle CDB, the side CB and all the angles being known, the side BD may be found, as in art. 52. Book III.

ANSWER. The depth of water DB is 48,71 fathoms.

QUESTION XIX. *Coming within sight of two headlands bearing North and South of each other, the southern one bore from the ship due East, and the other NE. b. E.; and after sailing due East 5 miles, the northern headland bore NE. b. N. $\frac{1}{2}$ E.: Required the distance of those headlands from one another, and their distance from the ship at each time of setting them.*

In the east and west line take BA = 5 miles; draw the NE. b. E. and NE. b. N. $\frac{1}{2}$ E. rhumbs Bn, BD; through A draw AD parallel to Bn, meeting BD in D; draw DC perpendicular to AB continued.

Then D and C are the headlands; A, B, are the ship's places at the times of setting them, and AB the distance sailed.

Now $\angle A = (\angle CBn \text{ by II. } 95 =) 3 \text{ points}$; the $\angle DBC = 4\frac{1}{2} \text{ points}$.

Then $\angle ABD = 11\frac{1}{2} \text{ pts. (II. } 91)$; $\angle ADB = \frac{1}{2} \text{ pt.}$ and $\angle BDC = 3\frac{1}{2} \text{ pts.}$

In the triangle ABD having the side AB, and the angles given, find the sides AD, BD, by art. 52. Book III.

And in the right angled triangle BCD, knowing the side BD, and all the angles, find the sides BC, CD.

ANSWER. AD = 13,31 m. BD = 9,565 m. BC = 6,07 m. CD = 7,395 m.

QUESTION XX. *Having cast anchor, I observed the bearings of a tower, a mill, and a lighthouse, known to lie due east and west of one another; the tower bore WSW. the mill SW. b. S. $\frac{1}{2}$ W. and the lighthouse S. b. W. $\frac{1}{2}$ W.; the distance of the tower from the mill is $5\frac{1}{2}$ miles: How far are each of those objects distant from the place where I anchored?*

Draw the given rhumbs Br, Bc, Bn; make BA = $5\frac{1}{2}$ miles; continue CB till it meets AD, drawn parallel to Br, in D; draw DC parallel to Bn: then D represents the ship's place, A the tower, B the mill, and C the lighthouse.

The angles are made out, and the triangles are solved, as in the last question.

ANSWER. DA = 9,021 m. DB = 4,46' m. DC = 3,608 m. and BC = 1,785 miles,

SECTION VII.

Of Sailing to Windward.

42. When the wind is directly, or partly, against a ship's direct course to the place she is bound to, she reaches her port by a kind of zigzag, or z like course; which is made by sailing with the wind first on one side of the ship, and then on the other.

In a ship, and looking toward the *stem* or *head*,

STARBOARD signifies the right hand side.

LARBOARD the left hand side.

FORWARD or AFORE, is toward the head or stem of the ship.

AFT or ABAFT, is toward the hinder part, or stern.

The BEAM signifies *athwart*, or across, the middle of the ship.

43. When a ship sails the same way that the wind blows, she is said to sail or run before the wind; and the wind is said to be *right aft*, or *right astern*; and her course is then 16 points from the wind.

When the ship sails with the wind blowing directly across her, she is said to have the *wind on the beam*; and her course is eight points from the wind.

When the wind blows obliquely across the ship, the wind is said to be *abast the beam*, or *before the beam*, according as her course is more or less than eight points from the wind.

When a ship endeavours to sail towards that point of the compass from which the wind blows, she is said to *sail on a wind*, or to *ply to windward*.

A vessel sailing as near as she can to the point from which the wind blows, is said to be *close hauled*. The generality of ships will lie within about six points of the wind; but sloops, and some other vessels, will lie much nearer.

44. The *windward*, or *weather side*, is that side of the ship on which the wind blows; and the other side is called the *leeward*, or *lee side*.

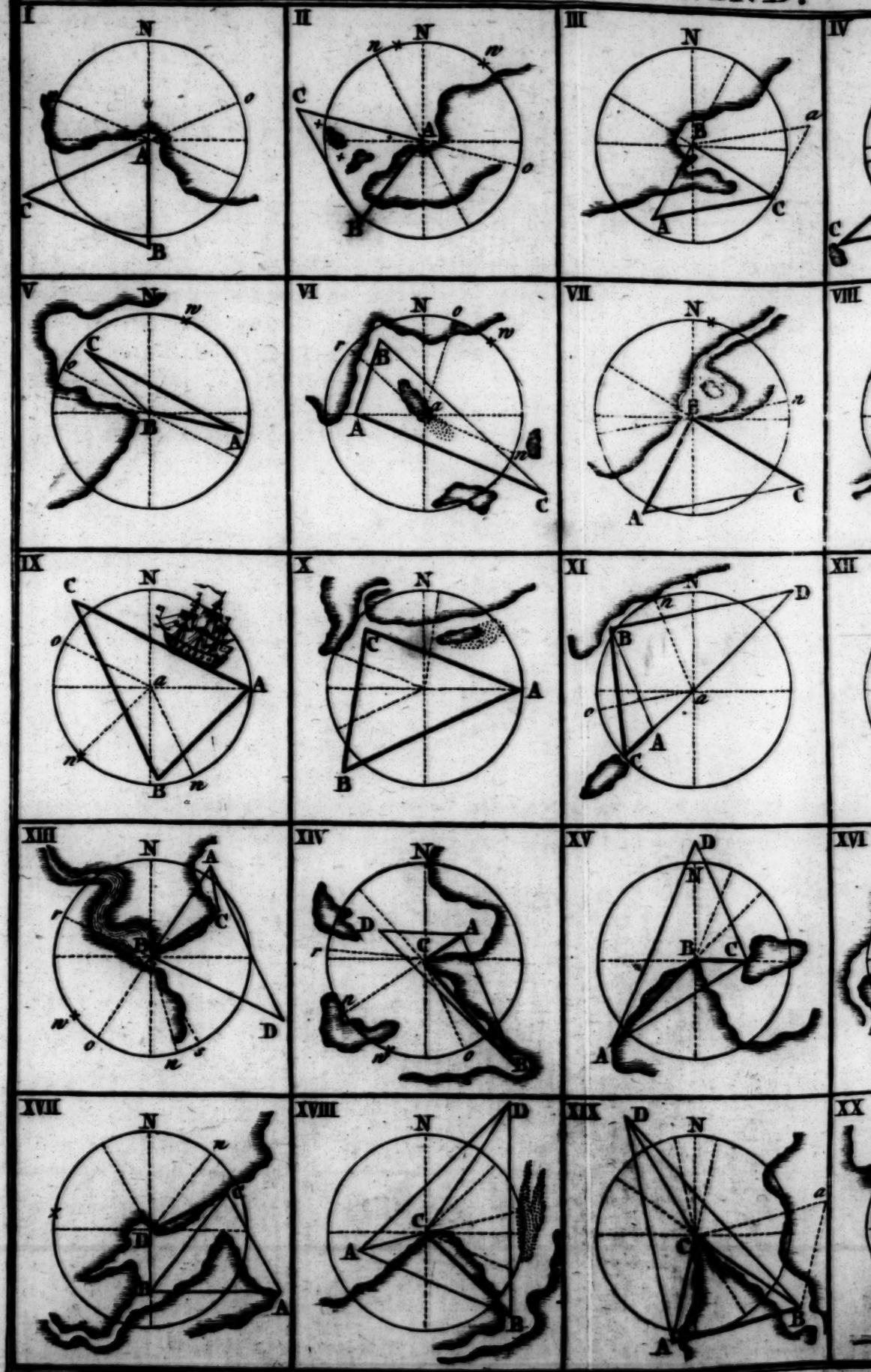
Tacks and *sheets* are large ropes made fast to the lower corners of the fore and main sails, by which either of these corners is hauled fore or aft.

When a ship sails on a wind, the *windward tacks* are always hauled forward, and the *leeward sheets* aft.

The *starboard tacks* are *aboard*, when the starboard side is to windward, and the larboard to leeward.

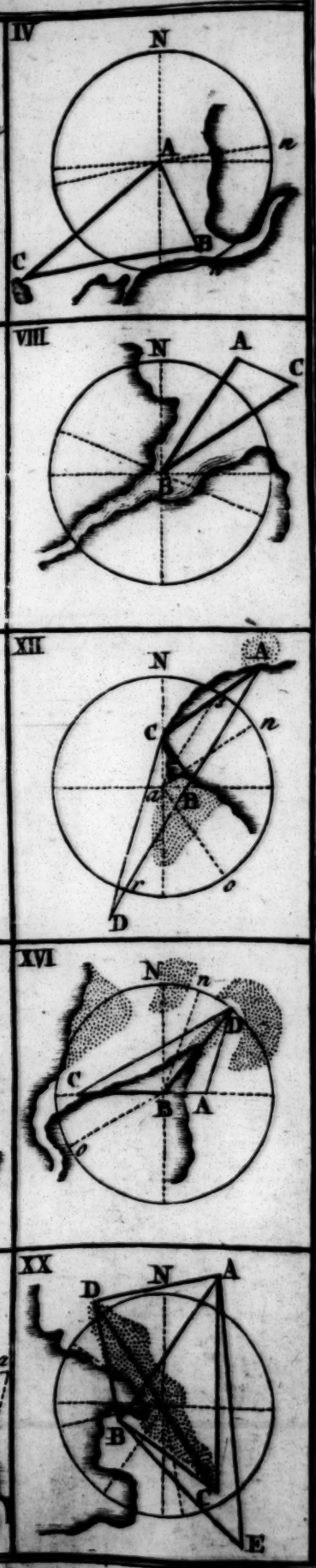
And the *larboard tacks* are *aboard*, when the larboard side is to windward, and the starboard to leeward.

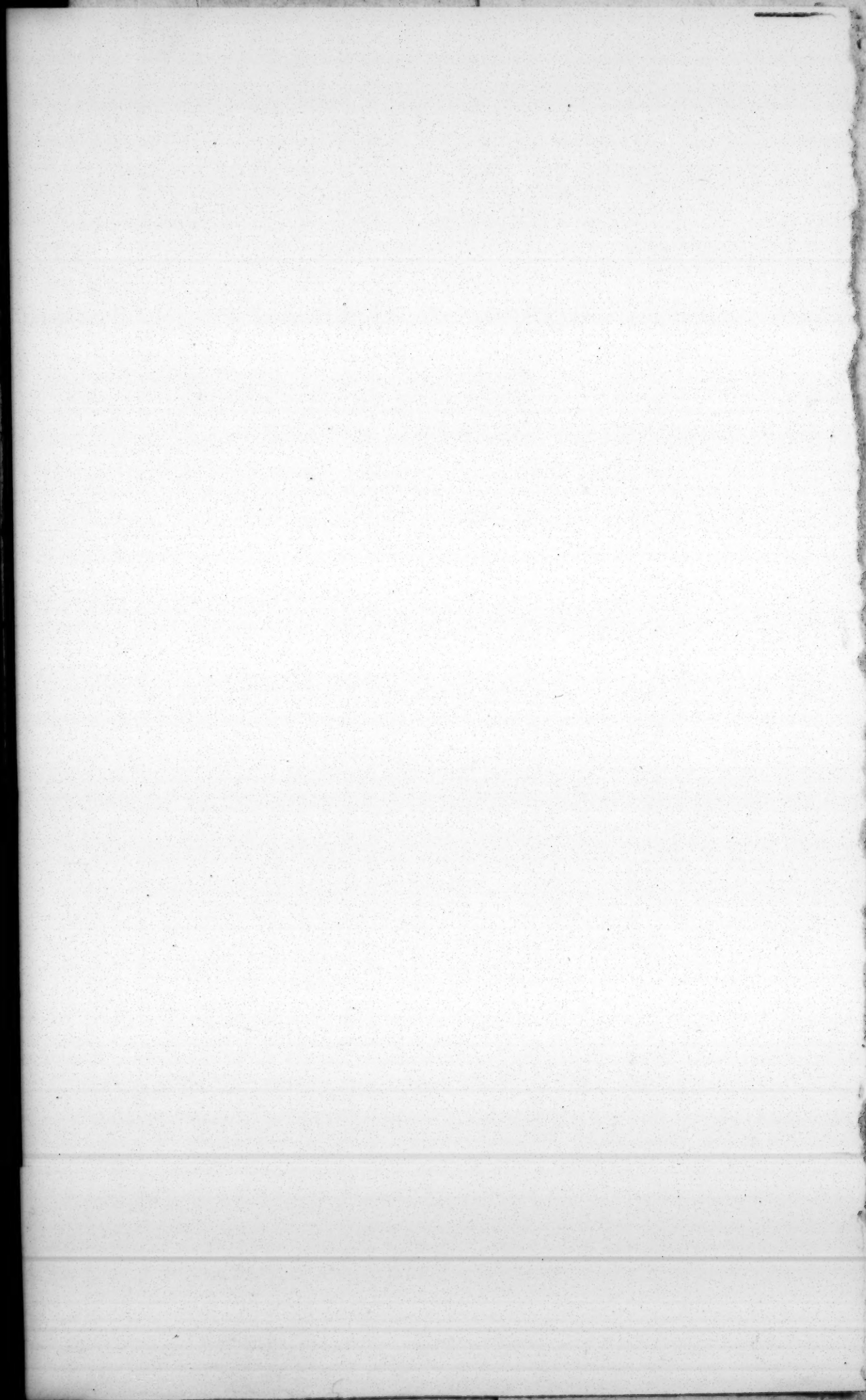
45. To know how near the wind a ship will lie; observe the course she goes on each tack, when she is close hauled; then half the number of



S. Jefferys sculp.

Pl. IX.





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of points between the two courses, will shew how near the wind that ship will lie.

46. The most common cases in turning to windward may be constructed by the following precepts:

Having drawn the meridian and parallel of latitude (or east and west line) in a circle representing the horizon of the place, mark the place of the wind in the circumference; draw the rhumb passing through the place bound to, and lay on it the distance of that place from the center.

On each side of the wind, lay off, in the circumference, the points or degrees shewing how near the wind the ship can lie; and draw these rhumbs.

Now the first course will be on one of these rhumbs according to the tack the ship leads with. Draw a line through the place bound to, parallel to the other rhumb and meeting the first, and this will shew the course and distance on the other tack.

The figures referred to in this section are in Plate IX. at the end; where they are marked by the number of the question.

QUESTION I. *The wind is at north, and I am bound to a port 25 miles directly to windward, being on my starboard tacks, and can lie within 6 points of the wind: What must be my course and distance on each of two tacks to reach my port?*

The construction being done as above directed, N is the place of the wind, A the port bound to, and B the place where the ship is supposed to be, when the port is 25 miles to windward of her.

Now as the ship leads with her starboard tacks, that is, has the wind blowing on her starboard side, she must first sail along the line BC drawn parallel to the rhumb AN, which is 6 points from the wind; and the place where the other rhumb AB, also 6 points from the wind, being produced from A toward C, meets with BC in the point C, is the place where she must tack about to reach her port within 6 points of the wind on her larboard tack.

Here BC being parallel to AN, the $\angle B = (\angle NAB \text{ by II. 95} =) 6 \text{ points.}$

And the $\angle BAC = (\angle NAB, \text{ by II. 93} =) 6 \text{ points; hence } \angle C = 4 \text{ points.}$

Therefore, as $\angle B = \angle BAC$; the side BC = side CA. (II. 104)

Now as one side AB, and all the angles are given, the solution falls under Article 45. Book III.

Therefore, As $\sin \angle C : AB :: \sin \angle BAC : BC.$

Or, As $\sin 45^\circ 00' : 25 \text{ m.} :: \sin 67^\circ 30' : 32,66.$

ANSWER, the ship sails { on her starboard tacks *WNW*. 32,66 miles.
on her larboard tacks *ENE*. 32,66 miles.

QUESTION

QUESTION II. *A ship that is bound to a port 80 miles directly to windward, then at NE. b. N. $\frac{1}{2}$ E. proposes to reach her port at two boards each within 6 points of the wind: Required her course and distance on each tack, so as to double a rocky shelf lying in the NW. quarter.*

As the wind is in the NE. quarter, and the ship is to double a shelf in the NW. quarter, she must lead with her starboard tacks; and running from B, her present place, to C in a parallel to the rhumb A n, 6 points from w the place of the wind, she then tacks for her port A, in the direction of the rhumb A, o, 6 points from w.

The manner of solution is the same as in the last question.

ANSWER, she runs on her $\left\{ \begin{array}{l} \text{starboard tacks NNW. } \frac{1}{2} \text{ W. } 104,5 \text{ miles.} \\ \text{larboard tacks ESE. } \frac{1}{2} \text{ E. } 104,5 \text{ miles.} \end{array} \right.$

QUESTION III. *A ship bound to a port bearing NNE. $\frac{1}{2}$ E. must double a cape to the eastward. Now she having run on her larboard tack 15 leagues within 6 points of the wind then at N. b. E. the port bore NW. b. W. $\frac{1}{4}$ W.: It is required, how near the wind she must lie on her starboard tack, and what is the distance of the port at each time of setting it?*

Here A is the place of the ship at first, B the port bound to; AC is the run on the larboard tack, and CB that on the starboard tack.

ANSWER. $\left\{ \begin{array}{l} \text{The distance AB from the port is } 10,08 \text{ leagues.} \\ \text{The run CB is } 11,61 \text{ leagues, and } 6\frac{1}{4} \text{ points from the wind.} \end{array} \right.$

QUESTION IV. *A ship being bound to a port bearing SSE. and directly to windward, having run on her larboard tack $83\frac{1}{4}$ miles within $6\frac{3}{4}$ points of the wind, on tacking about falls in with a rock at the same distance from her port. What course must she run on her starboard tack, how near the wind, and what was the port's distance at first?*

Here the side AC=CB; therefore $\angle B = \angle BAC = 6\frac{3}{4}$ points.

Hence $\angle C = 2\frac{1}{2}$ pts. Also $\angle B = \angle BAN = 6\frac{3}{4}$ pts. Therefore $\angle NAW = 7\frac{1}{4}$ points.

ANSWER. $\left\{ \begin{array}{l} \text{Starboard course E. b. N } \frac{1}{4} \text{ E. } 6\frac{3}{4} \text{ points from the wind.} \\ \text{The port's distance at first was } 40,47 \text{ miles.} \end{array} \right.$

QUESTION V. *A privateer lying by with the wind at NNE. sees a sloop on her starboard tacks, that had just doubled a point 18 miles to the W. b. N.; the sloop run for her port within 6 points of the wind; the privateer gave chase at the rate of eight knots an hour, and in four hours came up with her: Required the sloop's rate of sailing, and also the courses of both vessels.*

Draw BA to the E. b. S. and equal to 18 miles; on A with $32 \text{ m.} = 8 \times 4$, cut the rhumb BC, drawn six points from the wind, at w. Then the

the privateer is first at A, sees the sloop at B, gives chase along the line AC, and takes the sloop at C; and B^o drawn parallel to AC shews the privateer's course from the north.

Here are known two sides, AB, AC, and the $\angle ABC = 13$ points.

ANSWER. $\left\{ \begin{array}{l} \text{The sloop sails NW. at the rate of } 3,86 \text{ m. per hour} = \frac{BC}{4}. \\ \text{The privateer's course N. } 63^{\circ} 12' \text{ W.} \end{array} \right.$

QUESTION VI. *Being within sight of my port, bearing N. b. E. $\frac{1}{2}$ E. distant 18 miles, a fresh gale sprung up at N. E.; then running 48 miles on my larboard tacks within six points of the wind, I tacked about: Required the course and distance to my port.*

From any point A draw AB, AC, parallel to a ^o, a ⁿ, the N. b. E. $\frac{1}{2}$ E. and ESE. rhumbs, the latter being six points from the wind at NE.

Make AB=18, AC=48, and join BC. Then the ship, at A, first sees her port at B, and sailing from A to C on the larboard, must go from C to B on the starboard tacks.

Here then are known two sides, and the included angle A = $8\frac{1}{2}$ points. Therefore the solution will be as in Article 48. Book III.

ANSWER. The ship has to sail 52,89 miles on a course N. $47^{\circ} 42'$ W.

QUESTION VII. *A ship bound to a port met a sloop, that had sailed from thence SSW. $\frac{1}{2}$ W. 325 miles, the wind being at N. b. E.; afterward, the ship having plied on her larboard tack for three days, met a vessel which had sailed on a direct course SE. b. E. $\frac{1}{2}$ E. 412 miles, since she departed from that port: Required the ship's course and distance between her meeting those vessels, and how near the wind she lay.*

Here B is the port bound to, A and C are the points where the ship met the vessels, and AC the distance run; parallel to which, a line Bⁿ being drawn, will shew the course and distance from the wind.

ANSWER. The distance AC = 524,8 m. The course is N. $79^{\circ} 51'$ E. $6\frac{1}{4}$ points from the wind.

QUESTION VIII. *Hoving my starboard tacks on board, I met a snow that had sailed NE. b. N. 284 miles from the port I am bound to, and next day I met a brig which had sailed from thence 326 miles, with the wind then at S. b. E., two points abaft the beam: Required my course and distance between the meeting these vessels, and how near the wind I had lain.*

Here B is the port, A and C the places of meeting.

There are known two sides and the contained angle.

ANSWER. $\left\{ \begin{array}{l} \text{The ship had sailed S. } 64^{\circ} 6' \text{ E. } 4\frac{3}{4} \text{ pts. from the wind.} \\ \text{The distance run was 125,9 miles.} \end{array} \right.$

QUESTION

QUESTION IX. *The wind at SW. and a ship plying to windward, after running 450 miles on her larboard tacks, and 450 on her starboard tacks, finds she has got 300 miles directly to windward: What were her courses, and how near the wind?*

From any point A draw $AB = 300$ miles, and parallel to the wind rhumb aw ; on A, B, with 450 miles, describe arcs cutting in c; then the lines AC, CB, being drawn, will shew the distances run on each tack.

The point c is taken towards the NW. quarter, as the ship leads with her larboard tacks; but had she led with her starboard, the point c must have been taken toward the SE. quarter.

The rhumbs ao , an , being drawn parallel to AC, CB, will shew the courses on each tack.

Here are the three sides given to find the angles; but two of the sides being equal, the solution is readily performed, as in Art. 64. Book III.

ANSWER. $\left\{ \begin{array}{l} \text{Course on larb. is N. } 64^{\circ} 28' \text{ W.} \\ \text{Course on starb. is S. } 25^{\circ} 32' \text{ E.} \end{array} \right\} 6\frac{1}{4} \text{ pts. from the wind.}$

QUESTION X. *A pirate gave chase to a sloop, 15 miles a-head to the WSW. and both on their starboard tacks, the wind at NW.; the sloop finding she lost way, tacked about for an island in the NW. quarter, 11 miles distant from her, and 13 from the pirate: Required how near the wind the sloop must run to fetch the island, and whether the pirate can lie up for it or not.*

ANSWER. $\left\{ \begin{array}{l} \text{The sloop's course is N. } 10^{\circ} 05' \text{ E. } 5 \text{ pts. from the wind.} \\ \text{The pirate's course is N. } 66^{\circ} 54' \text{ W. } 2 \text{ pts. from the wind.} \\ \text{Therefore he cannot fetch the island.} \end{array} \right.$

QUESTION XI. *Being on a NE. course with my larboard tacks on board, an island bore SW. distant 12 miles, and my port bore NNW.; the distance of the island and port is 40 miles: now the wind is at NNW. $\frac{1}{2}$ W. and I can lie no nearer the wind than $6\frac{1}{2}$ points: Required how far I must run on my present course before I tack about, and also the course and distance I have then to steer.*

In a SW. rhumb, from any point A, take $AC = 12$ miles; and on c with a distance of 40 miles cut AB drawn parallel to the NNW. rhumb an ; now the rhumb ao being taken $6\frac{1}{2}$ points from the wind, through B draw BD parallel to ao , meeting CA continued in D.

Then A is the ship's place, c the island, B the port bound to; AD is the distance to run on her larboard tacks, and BD on the starboard.

In the triangle CBA there are known CA, CB, and $\angle CAB = \angle Can = 10$ pts.; then finding AB (III. 57) in the triangle ABD, one side and all the angles being known, the sides AD, DB, are found, as in Art. 54. B. III.

The $\angle D = \angle Cao = 3$ pts. $\angle BAD = \angle Dan = 6$ pts. $\angle ABD = 7$ pts.

ANSWER. $\left\{ \begin{array}{l} \text{The distance run on the NE. course is } 59.75 \text{ miles.} \\ \text{On the starboard she must run W. b. S. dist. } 56.28 \text{ miles.} \end{array} \right.$

QUESTION

QUESTION XII. *A ship sailing close by a point sees two lighthouses, one 18 miles to the NE. b. E. the other eight miles to the SE. b. S.; the ship is on her larboard tacks, within $6\frac{1}{4}$ points of the wind, then at SE. b. E.: Required how far she must run to bring the lighthouses to bear in one line; and what will be the bearing and distances of them from the ship at that time.*

From any point *c* draw *CA* parallel to *an* the NE. b. E. rhumb, and equal to 18 miles; also draw *CB* parallel to *ao* the SE. b. S. rhumb, and equal to eight miles; join *AB*, and produce it until it meets the line *CD*, drawn parallel to *ar*, a rhumb $6\frac{1}{4}$ points from the wind at SE.

Then *c* is the ship's place at first; *A*, *B*, are the lighthouses; *CD* the distance run to see them in one right line *DBA*; then a rhumb *as*, drawn parallel to *DA*, shews their bearing at that time.

In the triangle *ACB*, knowing two sides and the included $\angle c = \angle naa = 8$ points, the other angles and side *AB* is found, as in Art. 46. B. III.

In the triangle *ACD*, knowing *CA*, the $\angle ACD = \angle nar = 13\frac{1}{4}$ points; also the $\angle A$ found before; the distance *CD*, *AD*, are found, as in Art. 55. Book III.

ANSWER. { The ship runs on her larboard S. b. W. $\frac{1}{4}$ W. dist. 23,38 m.
Then the lighthouses bear N. $32^{\circ} 17'$ E.
The distance of *A* being 38,66 miles, and of *B*, 18,96 miles.

QUESTION XIII. *A ship wants to reach a port bearing SW. b. S. at two boards, but must double a point bearing S. b. E. the point being 25 miles to the NE. b. E. of the port; the ship can lie no nearer the wind, now at SW. than $6\frac{1}{2}$ points: Required her course and distance on each tack.*

Take *c* the point, 25 miles to the NE. b. E. of *B* the port; through *c* draw *CA* parallel to *bn* the S. b. E. rhumb, and its meeting with *ob* the SW. b. S. rhumb produced northward, gives *A* the ship's place; then *AD* and *DB* being drawn in the direction of the rhumbs *bs*, *br*, $6\frac{1}{2}$ points from the wind at *w*, shew the runs on each tack.

In the triangle *ABC*, there are known *BC*, $\angle BAC = \angle obn = 4$ points, $\angle ABC = 2$ points, $\angle C = 10$ points; then *AB* is found, as in Art. 55. B. III.

In the triangle *ABD*, *AB* is now known, $\angle BAD = \angle obs = 5\frac{1}{2}$ points, $\angle ABD = \angle obr = 7\frac{1}{2}$ points, $\angle D = 3$ points; hence *AD*, *DB*, are found, as in Article 55. Book III.

ANSWER. { Course on starboard is SSE. $\frac{1}{2}$ E. distance 58,51 miles.
Course on larboard is NW. b. W. $\frac{1}{2}$ W. dist. 51,85 miles.

QUESTION XIV. *A privateer lying behind a low point which was 6 miles to the SW. b. W. of her, sees a ship to the SSE. coming out of a port 18 miles distant from the point; the ship steered NW. with a brisk gale at SSW.; the privateer slipt his cable, and gave chase within $6\frac{1}{4}$ points of the wind, and takes her: How far had each run when they met?*

Take *A*, 6 miles to the NE. b. E. of *c* the point; from *c* with 18 miles cut *AB*, drawn parallel to *co* the SSE. rhumb, and *B* is the port the ship

ship sailed from; then AD drawn $6\frac{1}{2}$ points from the wind, meeting BD, drawn NW. the intersection D is the place where the privateer meets the ship.

In the triangle ACB, is given AC, CB, and $\angle CAB = \angle nco = 7$ points, to find AB.

Then in $\triangle ABD$, where $\angle DAB = \angle rco = 10\frac{1}{2}$ points, $\angle DBA = 2$ points; $\angle ADB = 3\frac{1}{2}$ points; find the sides AD, BD, as in Article 55. Book III.

ANSWER. $\left\{ \begin{array}{l} \text{The ship had sailed NW. distance 25,27 miles.} \\ \text{The privateer sailed W. b. N. } \frac{1}{2} \text{ W. distance 10,96 miles.} \end{array} \right.$

QUESTION XV. *A ship that can lie within 6 points of the wind, sees a headland 21 miles to the NE. which she is to weather, in order to reach an island, 9 miles to windward thereof; the wind being at east: What course, and how far must she go on each tack, she leading with the starboard?*

Draw BA=21 m. to the SW. BC=9 m. to the East, join AC; draw AD, CD, each 6 points from the wind; then A is the ship's place, B the headland, C the island, AD the run on the starboard tack, and DC that on the larboard.

In the $\triangle ABC$, is given BA, BC, $\angle ABC = 12$ points to find the other $\angle$ s, and AC.

Then in the $\triangle ACD$, is known AC, and all the angles, to find AD, DC.

Thus $\angle D = 4$ pts.; $\angle DCA = DCB + \angle BCA$; $\angle CAD = \angle BAD + \angle BAC$.

ANSWER. $\left\{ \begin{array}{l} \text{On the starboard she runs 39,19 miles on the NNE. rhumb.} \\ \text{On the larboard she runs 23,12 miles on the SSE. rhumb.} \end{array} \right.$

QUESTION XVI. *There is a certain port, to sail into which you must bring the port and a mill, 4 miles to the east thereof, to bear due west; at which time a beacon, 5 miles to the NE. b. N. $\frac{1}{2}$ E. of the mill, must bear N. b. E. $\frac{3}{4}$ E; you then steer directly for the beacon, and from thence to the port: Required the best wind, in the NW. quarter, for a ship that goes equally well on both tacks, together with the distance she must run on each tack from the said situation to the port.*

In the W. rhumb take BC=4 miles, and in the NE. b. N. $\frac{1}{2}$ E. rhumb take BD=5 miles, join DC, and parallel to the N. b. E. $\frac{3}{4}$ E. rhumb BN, draw DA, meeting CB continued in A.

Then C is the port, B the mill, D the beacon, and A the ship's place.

In the $\triangle BAD$, is given BD and all the angles, to find AD.

In the $\triangle CBD$, is given BC, BD, and angle CBD, to find the other angles and DC.

Draw the rhumb BO parallel to DC; then the $\angle nbo$ being bisected, will give the place of the wind as required.

ANSWER. $\left\{ \begin{array}{l} \text{She will run on her larb. N. b. E. } \frac{3}{4} \text{ E. distance 4,105 miles.} \\ \text{And on her starb. S. } 61^{\circ} 40' \text{ W. distance 8,145 miles.} \\ \text{The best wind is that blowing from the NW. } \frac{1}{2} \text{ W. nearly.} \end{array} \right.$

QUESTION

QUESTION XVII. *A ship in doubling a point directly to the east of her port, sees a lighthouse bearing NNW. $\frac{1}{2}$ W. which she knows lies NE. b. N. $\frac{1}{2}$ E. from the port, and is 10 miles to the NE. by E. $\frac{3}{4}$ E. of a beacon bearing due north of her port; the wind is at W. by N. $\frac{1}{2}$ W. and she can lie within five points: Required her distance on each tack, supposing that she leads with the larboard, and keeps close to the lighthouse when she tacks.*

Let D be the beacon; make DC=10 miles in the NE. b. E. $\frac{3}{4}$ E. rhumb, and C will be the lighthouse; draw CB parallel to the NE. b. N. $\frac{1}{2}$ E. rhumb DN, and its intersection B with the S. rhumb DB is the port; through B and C, lines being drawn parallel to the E. and NNW. $\frac{1}{2}$ W. rhumbs, their intersection A is the place of the ship.

In the $\triangle CBD$ there is given DC, and all the angles; hence BC may be found. (III. 55.)

In the $\triangle CBA$ there is known CB, and all the angles; hence AC is found, as in Article 55, Book III.

Here $\angle DBC = 3\frac{1}{2}$ points, $\angle BDC = 10\frac{1}{4}$ points, $\angle DCB = 2\frac{1}{4}$ points.

And $\angle ABC = 4\frac{1}{2}$ points, $\angle BAC = 5\frac{1}{2}$ points, $\angle ACB = 6$ points.

ANSWER. { The distance on the larboard tack is 12,49 miles.
The distance on the starboard tack is 14,25 miles.

QUESTION XVIII. *A ship that can lie on either tack within six points of the wind, then at ESE., having her starboard tacks aboard, sees her port directly to windward, and a headland that lies 6 miles to the NW. of her port, bore E. b. N.; now she wants to reach her port at two boards: Required her course and distance on each, and also the bearing and distance of the headland when she tacks.*

Let C be the headland, and B, six miles to the SE. be the port; through C and B draw lines parallel to the E. b. N. and ESE. rhumbs, their intersection A is the ship's place; lines drawn through A and B, parallel to the rhumbs, six points from the wind, will meet in D, the place where the ship must tack; draw DC, and this shews the position and distance of the headland from the ship when she tacks.

In the $\triangle ACB$ is given BC and all the angles; find AB=8,979.

In the $\triangle ABD$ is known AB and all the angles; find AD, BD.

In the $\triangle BCD$ is known BC, BD, and $\angle CBD$; find the other angles and CD.

Here $\angle ACB = 11$ points, $\angle CAB = 3$ points, $\angle ABC = 2$ points.

The $\angle BAD = 6$ points, $\angle ABD = 6$ points, $\angle ADB = 4$ points, and $\angle CBD = 4$ points.

ANSWER. { Ship runs on starboard 11,73 miles NE.
larboard 11,73 miles S.
Headland bears when she tacks S. $29^{\circ}32'$ W. dist. 8,607 m.

QUESTION XIX. *A ship, on her starboard tacks, passing by a point, saw her port eight miles to the E. b. N. and at the same time a cliff, which lay to the NW. b. W. of the port, bore N. b. E.; the ship could lie within $6\frac{1}{2}$ points of the wind, then at NE. b. E. $\frac{1}{2}$ E. on her starboard tack, and within seven points on the larboard; she proposes to reach the port on two boards: Required her course and distance on each, together with the bearing and distance of the cliff when she tacks about.*

Here the point c is taken for the cliff, in order to bring the figure within the limits; but if A, representing the ship's place, was taken at the center, the construction would be more simple.

In the E. b. N. rhumb, take $ca=8$ miles; draw ab parallel to the S. b. W. meeting cb , drawn SE. b. E. in B, which is the port bound to; draw BA parallel to ac , meeting the S. b. W. rhumb in A, which is the ship's place; through A draw AD, parallel to a rhumb $6\frac{1}{2}$ points from the wind, and through B draw BD parallel to a rhumb seven points from the wind, their meeting D is the place where the ship is to tack; then DC being drawn, shews the bearing and distance of the cliff from the ship when she tacks.

In the $\triangle CAB$, is given $BC=AB$ and all the angles, to find $CA=6,123$.

In the $\triangle ABD$, is given AB and all the angles, to find AB, BD.

In the $\triangle ACD$, is known AC, AD, and $\angle CAD$, to find the other angles and CD.

ANSWER. { Course on starboard is N. b. W. distance 14,96 miles.
 { Course on larboard is SE. b. S. $\frac{1}{2}$ E. distance 16,97 miles.
 { The cliff on tacking bore S. $25^{\circ} 21'$ E. dist. 9,596 miles.

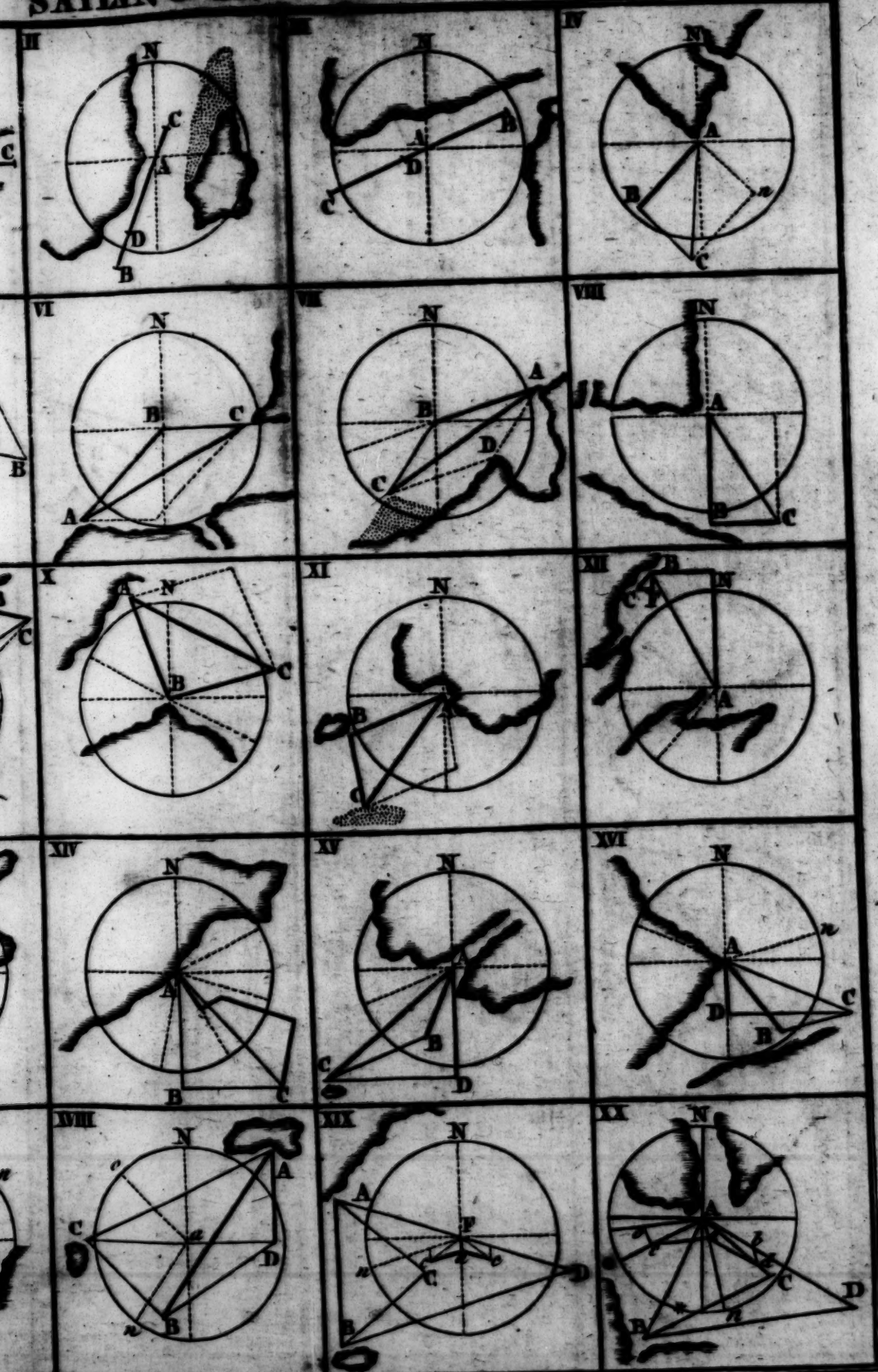
QUESTION XX. *A sloop at sea discovers two beacons at the extremities of a shoal, the one bearing W. b. S. and the other, which bore S. was nine miles to the S. E b. S. of the northern beacon; the port bound to is known to lie W. b. N. of one beacon, and S. b. W. of the other, and the vessel can lie within $6\frac{1}{2}$ points of the wind, then at SW.: Required the course and distance on each of two boards to gain her port; and also her bearing and distance from the port when she first saw the beacons.*

The construction and solution of this question being not much unlike the two last, are omitted here, to exercise the learner's skill.

ANSWER. { Course on starboard is SSE. $\frac{1}{2}$ E. distance 16,785 miles.
 { Course on larboard is NW. b. W. $\frac{1}{2}$ W. 16,054 miles.
 { Port bore S. $40^{\circ} 48'$ W. distance 9,56 miles.

SAILING IN CURRENTS.

PIX.



SECTION VIII.

Of Sailing in Currents.

47. A CURRENT or TIDE is a progressive motion of the water, causing all floating bodies to move that way toward which the stream is directed.

The *setting of a tide, or current*, is that point of the compass toward which the water runs; and the *drift of a current* is the rate it runs per hour.

The setting and drift of the most remarkable tides and currents are pretty well known; but in unknown currents the usual way to find the setting and drift, is thus:

Let three or four men take a boat a little way from the ship; and by a rope, fastened to the boat's stem, let down a heavy iron pot, or loaded kettle, into the sea, to the depth of 80 or 100 fathoms, when it can be: the boat will by this means ride almost as steady as at anchor. Then heave the log, and the number of knots run out in half a minute will give the miles which the current runs per hour; and the bearing of the log shews the setting of the current.

48. A body moving in a current may be considered in three cases:
Namely, Moving with, or the same way the current sets.

Moving against, or the contrary way to that which the current sets.

Moving obliquely to the current's motion.

When a ship sails with the current, it's velocity will be equal to the sum of it's proper motion and the current's drift.

When a ship sails against a current, its velocity will be equal to the difference of the current's drift and its own motion.

So that if the current drives stronger than the wind, the ship will drive astern, or lose way.

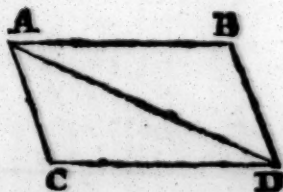
When the course set is oblique to the motion of the current, the ship's real course, or that made good, will be somewhere between that in which the ship endeavours to go, and the track in which the current tries to drive it: that is, it will always be along the diagonal of a parallelogram, in which one side represents the distance run by the ship, and the other adjoining side is the current's drift in the same time.

For suppose ABDC be a parallelogram, the diagonal of which is AD.

Now if the wind alone would drive the ship from A to B, in the same time as the current alone would drive it from A to C.

Then as the wind neither helps nor hinders the ship from coming toward the line CD, the current will bring it there in the same time as if the wind did not act.

And as the current neither helps nor hinders the ship from coming toward the line AB, the wind will bring it there in the same time as if the current did not act.



Therefore the ship must, at the end of that time, be found in both those lines, that is, in their meeting D.

Consequently the ship must have passed from A to D in the diagonal AD.

49. When the ship's course and distance by account, and the setting and drift of the current, are given, the true course and distance of the ship may be found, either by working a traverse, in which the setting and drift of the current are used as a course and distance; or by a trigonometrical solution of the triangles forming the figure: which is thus constructed.

From the center of a circle draw the ship's proper course and distance, and the current's setting and drift; with these two lines form a parallelogram, and from the center draw a diagonal, which will shew the ship's real course and distance.

50. It may frequently happen, that a ship is plying to windward across a tide's way. In such cases,

First construct the figure for the plying to windward.

Then with the course on each tack, and the setting of the current, form parallelograms; in each of which one side must be the ship's rate, and the other the current's drift.

And lines drawn to meet one another from the center and port bound to, parallel to the diagonals of those parallelograms, will shew the courses and distances which the ship must run on each tack.

The figures referred to in this section are at the end, in Plate X, where they are marked by the number of the question.

QUESTION I. *A ship sails E. five miles an hour, in a tide setting the same way four miles an hour: Required the ship's course, and the distance made good.*

The ship's motion is 5 m. E.
The current's motion is 4 m. E.

The ship's true run is 9 m. E.

In this case, as the ship sails from A, the same way the tide sets; therefore her motion will be quickened as much as the tide's motion is.

QUESTION II. *A ship sails SSW. with a brisk gale, at the rate of nine miles an hour, in a current setting NNE. two miles an hour: Required the ship's course, and the distance made good.*

The ship's motion is SSW. 9 m.
The current's mot. is NNE. 2 m.

The ship's true run is SSW. 7 m.

Here, because the ship sails in a contrary direction to the tide, its real motion will be slower than it appears to be by the drift of the current,

QUESTION

QUESTION III. *At ten o'clock in the forenoon, a ship that was running four miles an hour, came in sight of her port, bearing ENE. ; but finding, at three o'clock in the afternoon, that she had made no way, suspected a current, which on trial was found to set WSW. five miles an hour : What had been the course and real run of the ship during that time ?*

In this case, had there been no current, the ship in five hours would have gone a-head 20 miles from A to B : and had she been becalmed, she would have driven with the current 25 miles from A to C : consequently the difference, AD, of these two motions, is the distance the ship has run ; that is, she has driven aftern five miles.

QUESTION IV. *A ship in doubling a cape meets a strong tide setting SE. ; after running SW. 18 miles by the log, the cape bore N. $\frac{3}{4}$ E. : Required the distance of the cape, and the drift of the current.*

From A the cape, and center of the horizon, draw AB the SW. rhumb, equal to 18 miles ; through B draw BC parallel to the setting of the tide, or S. E. rhumb AN ; then AC being drawn S. $\frac{3}{4}$ W., its intersection, c, with BC, shews the ship's place ; and that she has run the line AC while the tide ran the length of BC, or AN .

In the triangle ABC there is given AB and all the angles, to find AC, BC.

The $\angle B = 8$ points, $\angle BAC = 3\frac{1}{4}$ points, $\angle ACB = 4\frac{3}{4}$ points.

ANSWER. { The ship has run 22,41 miles S. $\frac{3}{4}$ W.
 { The tide has run 13,35 miles SE.

QUESTION V. *A ship falling in with a current that set NNW. $\frac{1}{2}$ W. discovers a riff of rocks on the larboard, the eastern point of which is nine miles to the NE. b. N. $\frac{1}{2}$ E. ; and can be weathered by steering E. b. S. : Required the distance the ship must run by the log, and also the drift of the current.*

Here A is the ship's place, c the eastern point of the rocks to be weathered, AB the course she must shape in order to run along the line AC, which is the diagonal of the parallelogram formed by AB, the supposed run of the ship, and AN , the current's drift.

ANSWER. { The apparent run by the log is 10,76 miles.
 { And the drift of the current is 10,27 miles.

QUESTION VI. *A ship in crossing the mouth of a river, into which the tide set due east, sails from a buoy on the south side, NE. 10 miles, and then falls in with another buoy on the north side, distant from the first 15 miles : Required the ship's course, with the drift of the current.*

In the *SW.* rhumb take $BA=10$ miles; on *A*, with 15 miles, cut the *E.* rhumb, *BC*, in *c*: then *A* represents the southern buoy, *c* the northern one; *AB* is the ship's supposed run, *AC* the real run, and *BC* the drift of the tide.

Here there are given $AB=10$, $AC=15$, the $\angle B=12$ points.

ANSWER. { The ship's course is $N. 61^{\circ} 52' E.$
 { The tide's drift is 6,161 miles.

QUESTION VII. *At 11 o'clock in the evening, a lighthouse bore SW. b. S. and a strong tide was setting WSW. $\frac{1}{2}$ W. at the rate of $3\frac{1}{2}$ miles an hour; we steered directly for the lighthouse, and at four in the morning we passed over a sandy point $28\frac{1}{2}$ miles from the cape: Required the distance between the lighthouse and cape, also the course the ship has run.*

In the *ENE. $\frac{1}{2}$ E.* rhumb, take $BA=17\frac{1}{2}$ miles ($=3\frac{1}{2} \times 5$) for the tide's drift. On *A* with $28\frac{1}{2}$ miles cut the *SW. b. S.* rhumb in *c* the sandy point; through *A* and *c* draw lines parallel to *BC*, *AB*, and their intersection *D* is the lighthouse.

ANSWER. { The distance *AD* or *BC* is 12,72 miles.
 { The ship's course along *AC* is $S. 56^{\circ} 41' W.$

QUESTION VIII. *A ship running south at the rate of five miles an hour, in ten hours crosses a current, which all that time was setting east at the rate of three miles an hour: Required the ship's true course and distance sailed.*

Here the ship is first supposed to be at *A*, her imaginary course is along the line *AB*; but her real course is along the line *AC*, the diagonal of the parallelogram, the known sides of which are $AB=50$ miles ($=10 \times 5$), and $BC=30$ ($=3 \times 10$.)

ANSWER. The course is $S. 30^{\circ} 58' E.$ distance 58,31 miles.

QUESTION IX. *Suppose that in 24 hours a ship sails NE. 100 miles by the log, in a current setting E. b. S. $1\frac{3}{4}$ miles an hour: What is the course and distance made good?*

Draw *AB NE.* and equal to 100 miles, through *B* draw *BC* parallel to the *E. b. S.* rhumb, and make it 42 miles ($1\frac{3}{4} \times 24$); then draw *AC*, which shews the true run of the ship from *A*.

Here are given two sides, *AB*, *BC*, and $\angle B=11$ points.

ANSWER. The course is $N. 60^{\circ} 49' E.$ distance 128,2 miles.

QUESTION X. *A ship departs from her port at 8 o'clock in the evening, and sails before the wind, then at NNW. at the rate of $3\frac{1}{2}$ knots an hour, in a tide which runs at the same rate toward the eastward; and next day at noon she found herself 84 miles from her port: Required the ship's true course, and the setting of the tide.*

In the NNW. rhumb take $BA = 56$ miles ($= 3\frac{1}{2} \times 16$ h.); on A, with 84 miles, cut an arc described from B with 56 miles, their intersection C is the place the ship is come to, A being the port sailed from, AB the imaginary run before the wind, BC the drift of the current, and AC the real run of the ship.

Here $BA = BC$, and the solution is as in Article 63. Book III.

ANSWER. { The ship's true course is S. $63^{\circ} 55'$ E.
 { The setting of the current is N. $74^{\circ} 40'$ E.

QUESTION XI. *A ship departs in the evening for an island, 46 miles to the WSW. but by a strong tide running to the southward, she found herself next morning on a shoal 65 miles from her departed port, and 34 miles from the island: Required the bearing of her port, and the setting of the tide.*

Here A is the port sailed from, B the island bound to, c the shoal come to; the construction is as in the last, and the solution as in Art. 62. III.

ANSWER. { The port bears N. $37^{\circ} 37'$ E.
 { The current sets S. $4^{\circ} 46'$ E.

QUESTION XII. *A ship, in latitude $41^{\circ} 18'$, is bound to a port in latitude $46^{\circ} 30'$ N. lying 258 miles to the west; where being arrived, she finds by her dead reckoning that she has made 384 miles of northing, and 206 miles of westing: Required the setting and drift of the current that occasioned this difference.*

Here, by the dead reckoning, the ship should have gone from A to B; but she being arrived at the port C, the drift of the current will be represented by the line BC, and its setting by the angle FBC in the right angled triangle BFC; the legs of which, BF, FC, being the differences between the real and imaginary differences of latitude and departures.

For, the current setting southward, will cause the ship to be longer in getting to the northward, and increase her account of northing; and by its setting westward, it will quicken the ship's motion that way more than her account will shew.

ANSWER. The current's course is S. $35^{\circ} 50'$ W. and drift 88,82 m.

QUESTION XIII. *A ship from a place in latitude $37^{\circ} 40' N.$, sails SSW. distance 48 miles in 10 hours; then ESE. 72 miles in 14 hours; and has all the time been in a current setting SSW. $1\frac{1}{2}$ mile an hour: Required the ship's present latitude and departure, together with the direct course and distance she has sailed.*

As the current has run $1\frac{1}{2}$ mile an hour for 24 hours, its whole drift is 36 miles.

The best way of solving this question is to consider the current as another course and distance, and then with the three courses and distances form a traverse table, as shewn in Article 36.

TRAVERSE TABLE.					
Courses.	D.	N.	S.	E.	W.
SSW.	48		44,3		18,4
ESE.	72		27,6	66,5	
SSW.	36		33,3		13,8
			105,2	66,5	32,2
				32,2	
				34,3	

The southing and easting which the ship has made, being thus known, the direct course and distance will be found as in Art. 33.

Here the ship departs from A, and is come to C; AB being the diff. lat. and AC the departure,

ANSWER. { The present latitude is $35^{\circ} 55' N.$ departure 34,3 miles.
Direct course is S. $18^{\circ} 3' E.$ distance 110,7 miles.

QUESTION XIV. *Yesterday noon we were in latitude $28^{\circ} 14' N.$ and have sailed till this day noon the following courses, viz. SSE. $\frac{1}{2} E.$ 24 miles; NE. b. E. $\frac{1}{2} E.$ 15 miles; ESE. $\frac{1}{4} E.$ 45 miles; and all this time were in a current, setting S. b. W. $1\frac{3}{4}$ miles an hour: Required the ship's present latitude, departure, direct course, and distance.*

TRAVERSE TABLE.					
Courses.	D.	N.	S.	E.	W.
SSE. $\frac{1}{2} E.$	24		21,2	11,3	
NE. b. E. $\frac{1}{2} E.$	15	7,1		13,2	
ESE. $\frac{1}{4} E.$	45		15,2	42,4	
S. b. W.	42		41,2		8,2
		7,1	77,6	66,9	8,2
			7,1	8,2	
		D. lat.	70,5	58,7	Dep.

Here the current being considered as a course, the traverse table gives the diff. lat. = 70,5 miles.

And the departure = 58,7 miles. And hence the direct course is S. $39^{\circ} 47' E.$ and the distance is 91,73 miles.

In any question, where there are given one or more courses and distances sailed, and also the setting and drift of the current, the work may be performed as above.

The reason of this is pretty evident; for as each course and distance is affected by the current, therefore instead of correcting them one by one, as shewn in most of the preceding questions, they may be all allowed for together, by making a course and distance of the setting and drift of the current.

QUESTION XV. *At eight o'clock in the evening, a ship sailed from her port on a SSW. course, four miles an hour; a strong tide was then setting between the S. and W.; and at six o'clock in the morning she passed by a rock 70 miles to the westward, and 60 miles to the southward of her port: Required the setting and drift per hour of the tide.*

With 60 miles as a diff. lat. and 70 miles as a departure, find the place of the rock at c; A being the place sailed from; in the SSW. rhumb take $AB=40$ ($=4 \times 10$); draw BC, AC: then AB is the supposed run, AC the real run, and BC the drift of the tide.

In the $\triangle ADC$, is given AD, DC, $\angle D$; to find the $\angle A$ and $AC=92,2$.

In the $\triangle ABC$, is known AC, AB, $\angle CAB$; to find $\angle C$ and $BC=59,37$.

ANSWER. The tide set S. $67^\circ 09'$ W. and ran 5,937 miles an hour.

QUESTION XVI. *At six o'clock in the forenoon a ship weathered a cape in latitude $46^\circ 32'$ N.; and having run SE. b. S. 24 miles by the log in a current, found herself at noon in latitude $46^\circ 17'$ N. and the cape bore WNW.: Required the setting and drift of the current.*

Make AD=the diff. lat.; draw the departure DC, meeting the ESE. rhumb in c; draw AB, SE. b. S. and equal to 24 miles, and join BC.

Then A is the cape, c the place come to, AB the supposed run, BC the drift of the current, and AC the real run.

In the $\triangle ADC$, there is given AD and the angles; to find $AC=39,2$.

In the $\triangle ABC$, there is known AB, AC, $\angle BAC$; to find the angles, and $BC=23,41$ m.

Then drawing the rhumb An parallel to BC, it shews the setting of the current.

ANSWER. The current sets N. $77^\circ 47'$ E. and runs 3,9 miles an hour.

QUESTION XVII. *A ship being bound from Dover to Calais, which lies 21 miles to the SE. b. E. $\frac{1}{2}$ E.; and the tide of flood setting NE. $\frac{1}{2}$ E., $2\frac{1}{2}$ miles an hour: Required the course she must steer, and the distance she must run by the log, at the rate of six miles an hour, to reach her port.*

In the position of the SE. b. E. $\frac{1}{2}$ E. rhumb draw DC=21 miles; and parallel to the NE. $\frac{1}{2}$ E. rhumb draw DE= $2\frac{1}{2}$ miles; on E, with six miles, cut DC in F; draw DB parallel to EF, meeting CE, drawn parallel to DE.

Then D is Dover, c Calais; and the ship, by trying to sail along the line DB, will be driven between it and the direction of the current in the line DC.

ANSWER. The ship must sail S. $39^\circ 14'$ E. and will run by the log 19,4 m.

QUESTION XVIII. *Yesterday noon we were in latitude $42^{\circ} 20' N.$ and this day at noon find ourselves in latitude $41^{\circ} 10' N.$; by our account we have sailed SW. b. S. 189 miles, and all the time have been in a current setting NW.: Required the ship's direct course and distance, with the current's drift per hour.*

Take $AD=70$ miles, the diff. lat.; draw AB parallel to an , the SW. b. S. rhumb, and equal to 189 miles; through B draw BC parallel to the NW. rhumb ao , meeting the departure DC , and join AC .

Then the ship from A supposes herself sailing along AB ; but by the action of the current is driven along AC .

In the $\triangle ADB$, there is given AD , AB , $\angle BAD$: Required the angles and $DB=136,4$.

In the $\triangle DBC$, there is known DB and the angles; to find $DC=192$ and $BC 123,1$.

In the $\triangle ADC$, there is known AD , DC , $\angle ADC$; to find the angles and $AC=204,4$.

ANSWER. { The course is S. $69^{\circ} 58'$ W. distance 204,4 miles.
The current's drift per hour is 5,13 miles.

QUESTION XIX. *There are two ports which lie 270 miles to the north and south of one another; a ship sails from the northern port, with her star-board tacks aboard, within 72 degrees of the wind, then at S., at the rate of four miles an hour, in a current that sets south, two miles an hour: Required her course and distance on each of two tacks to reach the southern port.*

Draw the line AD through F , the center of the horizon, S. $72^{\circ} E.$ and from any point, A , in that line, draw AB , due south, and $=270$ miles; through B draw BD parallel to Fn , a rhumb 72° from the wind; then if there were no current, the ship must have sailed from A to D on the star-board, and from D to B on the larboard tacks: but to allow for the current, take $Fa=2$ miles, draw ac , ac , parallel to FD , Fn , and make ac , ac , each $=4$ miles; draw the diagonals Fc , Fc , of those parallelograms; then through A and B , lines drawn parallel to Fc , Fc , meeting in c , will shew the run of the ship on each tack.

Here the triangles Fac , Fac , being congruous by construction, therefore the $\angle CAB (= \angle aFc)$ is equal to $\angle CBA (aFc)$.

Now in the triangle aFc , there is given aF , ac , and $Fac=108^{\circ}$; from whence the other angles are known; viz. $\angle aFc=49^{\circ} 37'$. And in the triangle ABC there are known the side AB , and all the angles, whence the sides AC and CB are easily found.

ANSWER. { The course on starb. is S. $49^{\circ} 37'$ E. distance 208,4 miles.
The course on larb. is S. $49^{\circ} 37'$ W. distance 208,4 miles.

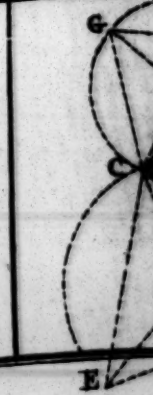
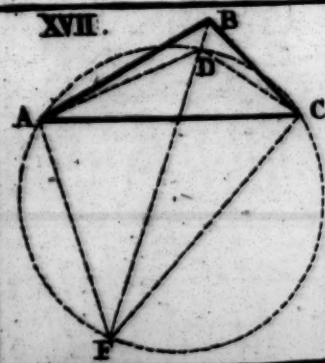
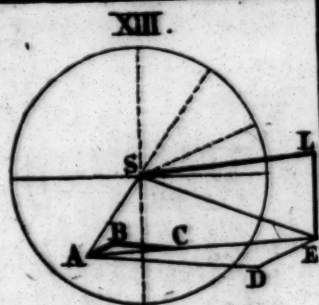
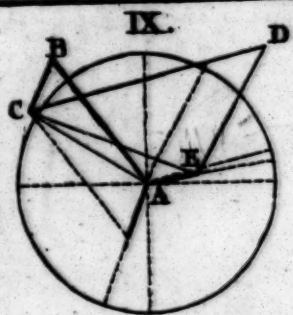
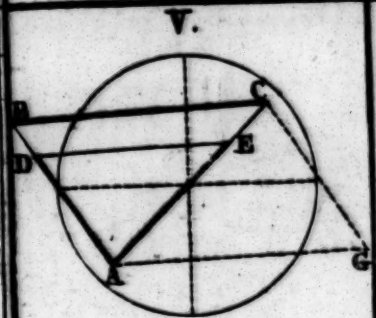
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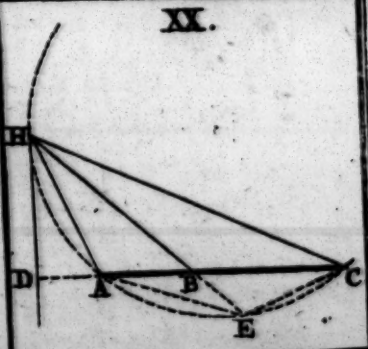
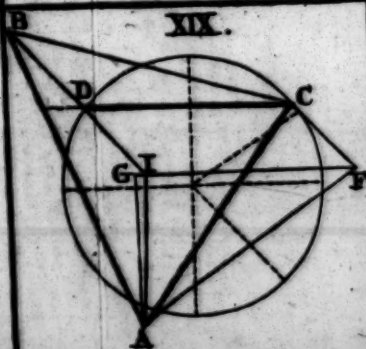
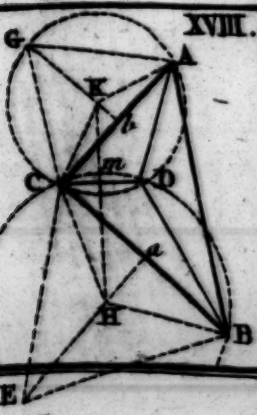
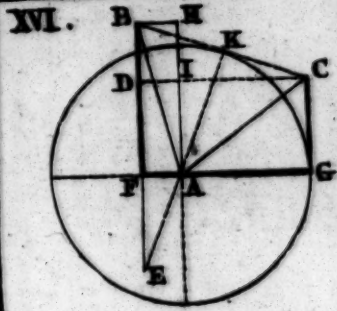
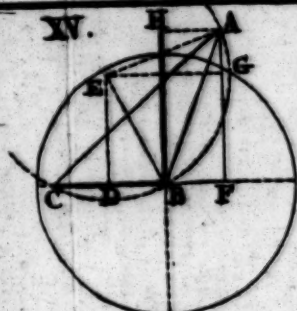
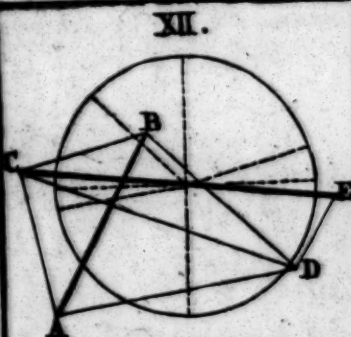
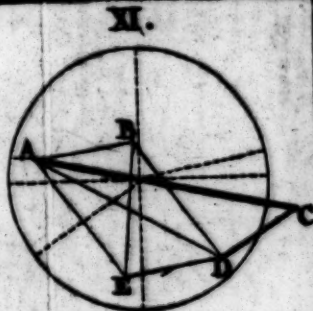
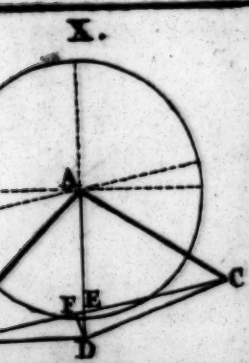
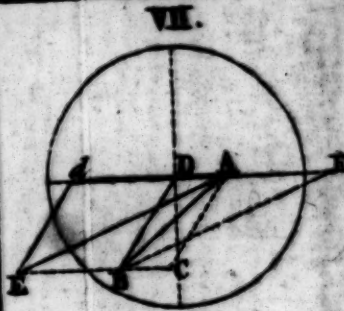
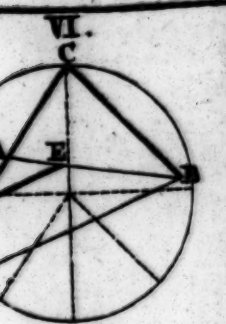
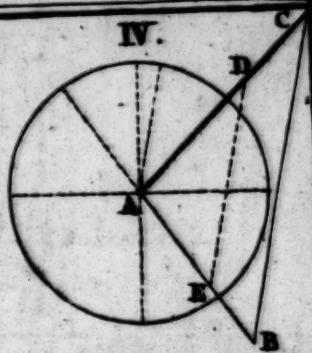
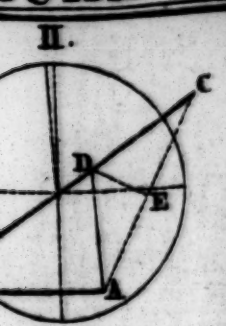
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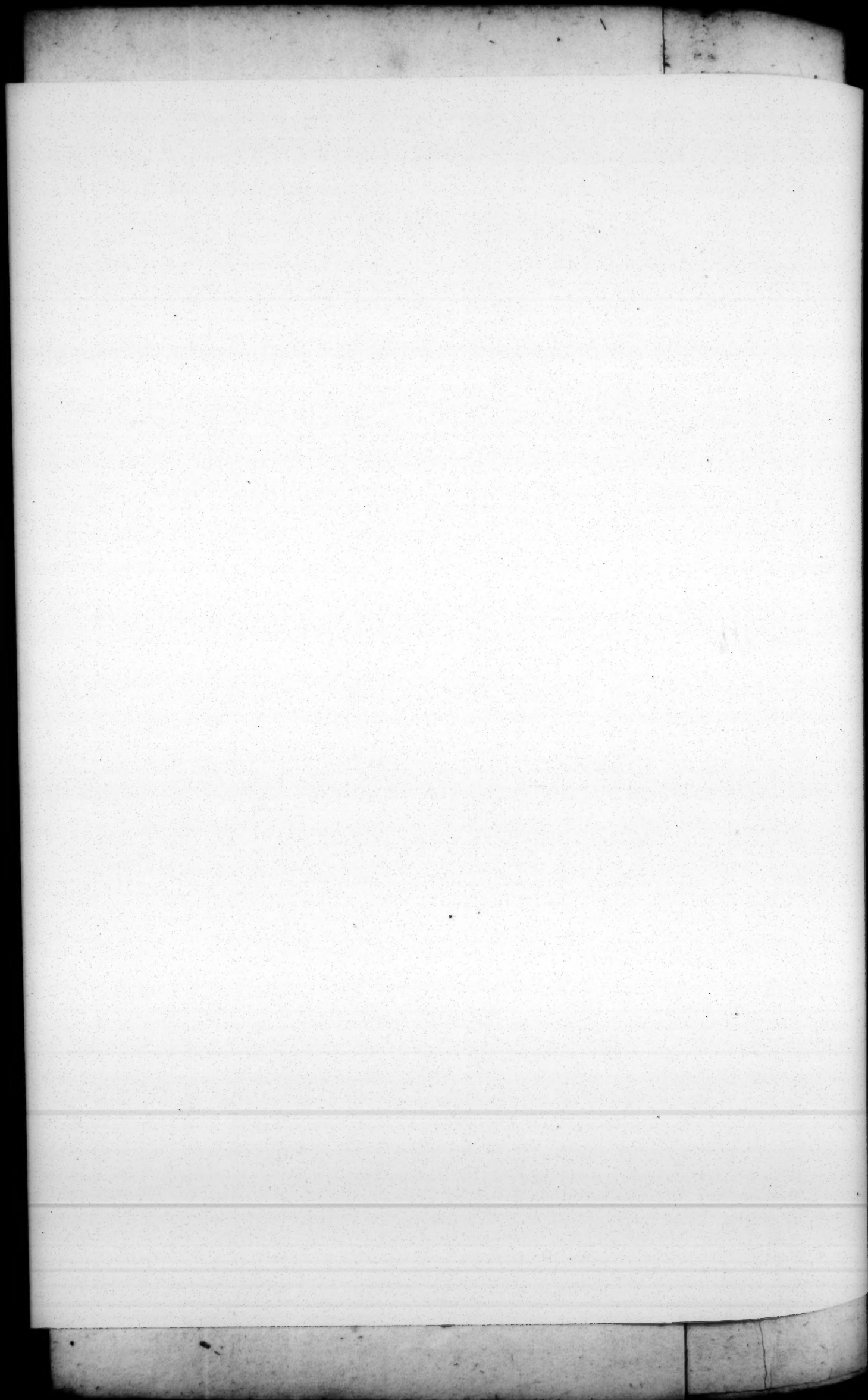
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QUESTION XX. *A ship that makes her way good within $6\frac{1}{2}$ points of the wind, is bound to a port bearing SW. b. S. $\frac{1}{4}$ W. distant 476 miles: Now the wind being S. b. W and a current setting S. b. E. $2\frac{1}{2}$ miles an hour, and the ship sailing $7\frac{1}{2}$ miles an hour: Required the course and distance she must sail on her starboard and larboard tacks to gain the port.*

In the SW. b. S. $\frac{1}{4}$ W. rhumb, take $AB=476$ miles; and, through A and B, draw the lines AD, BD, in the direction of rhumbs $6\frac{1}{2}$ points from the wind at S. b. W.; then, were there no current, the ship would sail on the lines AD, DB.

With the drift of the current $aA=2\frac{1}{2}$, and the run of the ship $7\frac{1}{2}$ miles an hour, taken in rhumbs Aa, Ab, $6\frac{1}{2}$ points from the wind; complete the parallelograms, the diagonals of which Ac, Ad, shew the courses the ship will move in, with the compound motions of the current's drift and ship's run.

Then AC and BC, drawn parallel to ac, will shew the run of the ship on the starboard and larboard tacks.

In the $\triangle A a d$ are given Aa, ad, $\angle A a d$; to find the $\angle d A a=37^{\circ} 41'$.

In the $\triangle A a c$ are given Aa, ac, $\angle A a c$; to find the $\angle c A a=74^{\circ} 54'$.

Then $\angle B A C=\angle B A a+\angle C A a=85^{\circ} 30'$.

Also $\angle n A c-\angle n A B=B A a=\angle A B C=27^{\circ} 05'$. (II. 93)

Consequently in the triangle ACB, there are known one side AB, and all the angles; by which the sides AC, CB, may be found.

ANSWER. { The course on the starb. is S. $48^{\circ} 56'$ E. dist. 234.7 miles.
The course on the larb. is S. $63^{\circ} 39'$ W. dist 514 miles.

Most of the Questions in the three preceding sections, although not of such common use at sea, as those in sections the IVth and Vth, yet have their uses on various occasions, as will evidently appear from many of the questions themselves. But there is another excellent use to be derived from their solution, that does not appear at first sight so evident to learners; which is, the furnishing them with an agreeable opportunity of exercising their talents in the application of Geometry and plain Trigonometry. For it should be well observed, that as all the operations relating to sailing depend chiefly on the principles of Trigonometry; so the persons, to whom these principles are most familiar, will with the greatest readiness not only apply them to the cases of sailing, but also see more clearly the reason of every step they shall find themselves necessitated to take. And as a further exercise for the understandings of those who are desirous of extending their notions this way, it has been thought proper to annex the Questions in the following section, with their solutions.

SECTION IX.

51. *A Collection of Practical Questions.*

The figures belonging to the questions in this section are in Pl. XI. and numbered the same as the questions.

QUESTION I. *A ship in latitude $47^{\circ} 30' N.$ and bound to a port in latitude $42^{\circ} 00' N.$ and 120 miles to the west, proposes to reach her port by running equal distances on each tack, the first to be on the meridian: What must the course be on the second tack, and how far on each?*

SOLUTION. With the given difference of latitude $= 330$, and the departure $= 120$, construct the triangle ABC ; from E , the middle of AC , draw ED at right angles to AC : then drawing DC , the lines AD , DC , will be the distances the ship must run on each tack.

For ADC is by construction an isosceles triangle.

In the triangle ABC , find the angle A (III. 46) $= 19^{\circ} 59' = \angle ACD$; the $\angle ACD + \angle CAD = \angle BDC = 39^{\circ} 58'$, the second course, in the SW. quarter. (II. 93)

In the triangle CBD , find (III. 45) $DC = 186,8$.

ANSWER. The first course is S., the 2d S. $39^{\circ} 58' W.$; and the distance on each tack 186,8 miles.

QUESTION II. *A ship having sailed NE. b. E. from a port in latitude $42^{\circ} 18' N.$, met a sloop which had sailed from a port in the same latitude, lying 92 miles to the east of the ship's port: the sum of their distances made 159 miles: Required their respective courses and distances.*

SOLUTION. In an east and west line take $BA = 92$ m., from B draw on the NE. b. E. rhumb $BC = 150$ m. join CA ; then ED , drawn at right angles to CA , from E , the middle, gives D , so that $DA = DC$. (II. 93)

In the triangle ABC , find (III. 48) the $\angle BAC = 114^{\circ} 27'$, and $\angle ACD = \angle CAD = 31^{\circ} 47'$.

Then $\angle BAC - \angle CAD = \angle BAD = 82^{\circ} 40'$; hence $\angle BDA = 63^{\circ} 35'$.

In the triangle BAD , find (III. 45) $BD = 101,9$ m., and $AD = 57,7$ m.

ANSWER. The ship sailed NE. b. N. 101,9 miles, and the sloop sailed N. $7^{\circ} 20' W.$ 57,7 miles.

QUESTION III. *Two ships A, B, sail from one road, their courses making an angle of $50^{\circ} 00'$; A sails between the S. and W. 40 leagues, B sailing between the S. and E. 50 leagues, has got 15 leagues to the southward of A: Required the course of each ship, also the bearing, distance, and departure from A to B.*

SOLUTION. With the given sides and included $\angle A$, construct the triangle ACB : On A , with 15 leagues, describe an arc at D , and from E , the middle of AB , with the radius EA , cut the former arc in D (II. 131;) draw the given diff. lat. AD , and the required departure DB : then C is the port sailed from, A one ship's place, B the other's.

In the triangle ACB , find (III. 48) the $\angle CAB = 78^{\circ} 24'$, and $\angle CBA = 51^{\circ} 36'$; the side AB will be found 39,1 leagues. In the triangle ADB , where AB , AD , are known, find $\angle DBA = 22^{\circ} 34'$, $\angle DAB = 67^{\circ} 26'$, and $BD = 36,1$.

ANSWER. A's course is S. $34^{\circ} 10' W.$ B's is S. $15^{\circ} 50' E.$; B bears from A S. $67^{\circ} 26' E.$ departure BD is 36,1 m. the dist. AB is 39,1 miles.

QUESTION

QUESTION IV. From two ports, bearing NW. b. N. and SE. b. S. two ships sail, the one NE. the other N. b. E.; they meet, and find that the sum of their distances added to the distance of the ports made 148 miles: Required the distance of the ports, and the run of each ship.

SOLUTION. Make a triangle ADE equiangular to the triangle required, in which one side, as AD, shall be of any assigned length, as 30; and by Art. 45. Book III. find $DE=41,61$; $AE=23,57$; and the sum of the three sides of the triangle ADE will be 95,18: then say,

As 95,18 : 148 :: AD=30 : AC=46,65.

And as 95,18 : 148 :: DE=41,61 : CB=64,70.

Then the other side AB will be 36,25 miles.

ANSWER. { The distance of the ports is 36,25 miles.
One ship's run is 46,65 miles, the other's 64,7 miles.

QUESTION V. Two ships meet at sea, bound to two ports distant from one another 12 miles: Now if one sails NW. b. N. six miles an hour, and the other NE. eight miles an hour, they will arrive at their respective ports at the same time: Required the distance each ship must run, and the bearing of those ports from one another.

SOLUTION. With the courses and rates of sailing make the triangle ADE, A representing the place of meeting; parallel to DE draw AG=12 miles; through G draw GC parallel to AD, meeting AE produced in C; through c draw CB parallel to AG, meeting AD produced in B; then B and c are the ports. For $AB:AC::6:8$; and $BC=12=AG$, BG being a parallelogram.

In the triangle ADE, knowing AD, AE, and $\angle A$, find $\angle D=60^\circ 30'$, $\angle E=40^\circ 45'$, and $DE=9,015$ miles; then $DE:BC::AE:AC=10,65$; :: $AD:AB=7,988$.

ANSWER. { One runs NE. 10,65 m; the other NW. b. N. 7,988 m.
c bears from B, N. $85^\circ 45'$ E.

QUESTION VI. A fleet of ships steering SW. b. S. four miles an hour, on seeing a sail, detached a cruiser, which gave chase SE. five hours at the rate of seven miles an hour, comes up with, and takes the chase. After an hour's time spent in adjusting matters on board the prize, she steers for the fleet, which still kept on the same course and rate: Required the course the cruiser must shape, and the distance she must run at seven miles an hour, to join them.

SOLUTION. Let c be the first place of the fleet, draw CD, SW. b. S. and CB, SE.; make $CB=35$ ($=7 \times 5$), $CA=24$ ($=4 \times 6$), and draw AB; then B is the place where the cruiser took the chase, and A the place where the fleet was when she left the chase: make $AF=4$, $FE=7$, draw BD parallel to FE, and D is the place where the cruiser joined the fleet.

In the triangle ACB, find $\angle CAB=63^\circ 25'$, and $\angle CBA=37^\circ 49'$, and $AB=38,39$. Then (II. 91) $\angle FAE=116^\circ 35'$. In the triangle FAE, find $\angle E=30^\circ 44'$ and $\angle F=32^\circ 41'$.

In the triangle ADB, similar to AFE, find $BD=63,58$ miles.

ANSWER. The cruiser must steer S. $66^\circ 26'$ W. and run 63,58 miles.

QUESTION

QUESTION VII. *A ship, sailing on a WSW. course, can sail from the port A to the port B in six days: But sailing at the same rate (by the log) on a NE. b. N. course, she goes from B to A in three days, a current setting all the way between the ports east, half a mile an hour: Required her dead reckoning outward and homeward, also the bearing and distance of A from B.*

SOLUTION. In the nine days outward and homeward-bound, the current runs at $\frac{1}{2}$ mile an hour, 108 miles east, that is 72 m. for outward, and 36 homeward. In an east and west line take $AD=36$, $Dd=72$; through A draw a WSW. rhumb, and through d draw a NE. b. N. and SW. b. S. rhumb, cutting the former in E: Through D, E, draw parallels to dE, dA, cutting in B; join AB, and draw BF parallel to EA, meeting dA produced in F; then A and B represent the two ports, AE the outward dead reckoning, BD the homeward, and AB the true distance.

For if $AF=BE=Dd=72$ is the drift of the current in the outward account, and the course shaped is along AE, the ship must run between AF and AE. Also if $BC=AD=36$ is the current's drift homeward, and the course shaped is along BD, the ship must run between BC and BD. But AB is the only common diagonal to the parallelograms FE and DC; consequently A and B are the ports.

In the triangle ADE, find (III. 45) $AE=161,6$; and $Ed=BD=72,39$ m.

In the triangle ADB, find (III. 48) $\angle DAB=39^\circ 39'$, and $\angle DBA=17^\circ 36'$. Also (III. 45) find $AB=99,04$.

ANSWER. { The dead reckoning outw. = 161,6 m. homew. = 72,39 m.
 { The true course is S. $21^\circ 21'$ W. distance 99,04 miles.

QUESTION VIII. *A ship, after doubling a cape and sailing NE. b. N. 45 miles, receives in the night considerable damage from a storm; she then bore directly toward a lighthouse lying 24 miles to the NW. of the cape, and having run 40 miles, and the day breaking, she discovers a port 42 miles to the north of the cape: What was her course and distance to that port?*

SOLUTION. Draw AD, NE. b. N. 45 m.; AB, N. 42 m.; AC, NW. 24 miles; join DC, make $DE=40$ m. and draw AE, EB; then A is the cape, c the lighthouse, and B the port.

In the triangle CAD, with the given sides and included angle A, find the $\angle C=70^\circ 58\frac{1}{2}'$, $\angle D=30^\circ 16\frac{1}{2}'$, and the side $CD=46,69$ miles.

In the triangle ADE, with the given sides and included angle D, find the $\angle DEA=87^\circ 08'$, $\angle DAE=62^\circ 36'$, and $AE=22,71$ miles.

In the triangle BAE, with the known sides AB, AE, and included $\angle EAB$, find $\angle BEA=124^\circ 47'$, $\angle B=26^\circ 22'$, and $EB=24,67$ miles.

ANSWER. { The course from E to B is N. $26^\circ 22'$ E.
 { And the distance EB is 24,67 miles.

QUESTION IX. *A ship running at the rate of $4\frac{1}{2}$ miles an hour, with the wind then at E. b. N., blowing two points abaft the beam; at five in the evening, being two leagues to the W. b. S. of a headland, she met the tide of flood setting SSW. at the rate of $1\frac{3}{4}$ miles an hour, and at nine that evening, a lighthouse which lay to the NNE. $\frac{1}{2}$ E. of the headland, bore ENE. $\frac{3}{4}$ E. : Required the ship's course and her distance from the lighthouse.*

SOLUTION. From five to nine is four hours, in which time the ship runs 18 miles, and the tide seven miles; also two points abaft the beam, or 10 points from the wind, is NW. b. N.

Suppose the ship at A; then in the E. b. N. rhumb take $AE=6$, and E is the headland; in the NW. b. N. take $AB=18$; through B draw BC parallel to the SSW. rhumb, and equal to 7, join CA, CE; through E draw a NNE. $\frac{1}{2}$ E. rhumb, meeting in D, an ENE. $\frac{3}{4}$ E. rhumb, drawn from C. Then C is the place which the ship arrives at, AC is her real run, and D the place of the lighthouse.

In the triangle ABC, where two sides AB, BC, and the included $\angle B$, are known; find $\angle BCA=101^{\circ} 19'$, $\angle BAC=22^{\circ} 25'$, and the side $AC=15,26$ miles.

In the triangle CAE, where there are known $AE=6$, $AC=15,26$, $\angle CAE=134^{\circ} 55'$; find $\angle AEC=32^{\circ} 47'$, $\angle ACE=12^{\circ} 18'$, and the side $CE=19,94$ miles.

In the triangle CED, where there are known $CE=19,94$ m. $\angle D=47^{\circ} 49'$, $\angle DCE=35^{\circ} 36'$, and $\angle DEC=96^{\circ} 35'$; the side ED will be found 15,67 miles, and the side $CD=26,74$ miles.

ANSWER. The ship's true course is N. $56^{\circ} 10'$ W.; dist. from the lighthouse 26,74 miles.

QUESTION X. *Two ships departed from a port at the same time, and after one had sailed SE. b. E. 40 miles, and the other SW. 50 miles, they were equally distant from a rock which lies directly south of their port: Required the bearing and distance of each from the rock.*

SOLUTION. From A, the port, draw AB SW. 50 miles, AC SE. b. E. 40 miles, join BC, and from F, the middle, draw FD at right angles to BC, meeting the meridian in D, the place of the rock, and join DB, DC, which are equal by Article 103, Book II.

In the triangle BAC, where there are known $AB=50$, $AC=40$, $\angle BAC=101^{\circ} 15'$; find $\angle ACB=44^{\circ} 35'$, $\angle ABC=34^{\circ} 10'$, and $BC=69,86$ miles.

In the triangle AEC, where there are known $AC=40$, $\angle EAC=56^{\circ} 15'$, $\angle ACE=44^{\circ} 35'$, $\angle AEC=79^{\circ} 10'$; find $EC=33,86$ miles.

Then $CF=(\frac{1}{2} BC)-EC=FE=1,07$.

In the right angled triangle FED, where are known $FE=1,07$, and $\angle FED=79^{\circ} 10'$; find the side $DF=5,591$.

In the right angled triangle DFC, where $DF=5,591$, $FC=34,93$; find the $\angle FDC=80^{\circ} 54'$, and $DC=35,38$ miles.

ANSWER. { The ship at B is 35,38 m. to the S. $88^{\circ} 16'$ W. of the rock.
 { The ship at C is 35,38 m. to the N. $70^{\circ} 04'$ E. of the rock.

QUESTION XI. Sailing *E. b. S.* $7\frac{1}{2}$ knots an hour, we saw two islands, one bearing *SE. b. S.* the other *E. b. N.*; the tide was then running *SW. b. W.* $2\frac{1}{2}$ miles an hour: two hours after, the first island bore *W. b. S.* and the other *N. W. b. N.*: Required the ship's course and distance, together with the bearing and distance of those islands from one another.

SOLUTION. In an *E. b. S.* rhumb, take $AC=15$ miles, ($=7\frac{1}{2}$ m. $\times 2$); through A, draw AB, AE, parallel to the *E. b. N.* and *SE. b. S.* rhumbs; draw CD *SW. b. W.* and equal to five miles, which the tide runs in two hours; through D, lines being drawn parallel to the *NW. b. N.* and *W. b. S.* rhumbs, their intersections with AB, AE, will give E, the place of the southern island, and B, the place of the northern one; join AD, BE.

In the triangle ADC, where $AC=15$, $DC=5$, and $\angle ACD=45^\circ 00'$; find the $\angle CDA=117^\circ 52'$, $\angle CAD=17^\circ 08'$, and $AD=12$ miles.

Now as ED is parallel to AB, and BD parallel to AE, therefore ABDE is a parallelogram; and so $AB=ED$, $AE=BD$.

In the triangle AED, where $AB=12$ miles, $\angle AED=112^\circ 30'$, $\angle DAE=27^\circ 52'$, and $\angle ADE=39^\circ 38'$; find $AE=8,286$ miles, and $ED=6,072$ miles.

In the triangle ABE, where $AE=8,286$ miles, $AB=6,072$ miles, and $\angle EAB=67^\circ 30'$; find $\angle ABE=69^\circ 15'$, the $\angle AEB=43^\circ 15'$, and the side $BE=8,186$ miles.

ANSWER. { The ship's course was *S. $61^\circ 37'$ E.* distance 12 miles.
The N. isle bore from the S. isle, *N. $9^\circ 30'$ E.* dist. 8,186m.

QUESTION XII. Coming out of a port, into which the tide of flood was then setting, I saw two headlands, the northern one, which bore *ENE. $\frac{1}{2}$ E.* was known to be 15 miles to the *NNE. $\frac{1}{2}$ E.* of the other, which then bore *S. b. E.*: after running *E. b. S. $\frac{1}{2}$ E.* 24 miles by the log, the northern headland bore *NW.* and the other *W. b. S.*: Required the setting and drift of the tide.

SOLUTION. In a *NNE. $\frac{1}{2}$ E.* rhumb take $AB=15$ miles; through A draw AC *N. b. W.* and AD *E. b. N.*; also through B draw BC *WSW. $\frac{1}{2}$ W.* and BD *SE.*; then C, the intersection of AC, BC, is the ship's place at first, and D, the meeting of BD and AD, is the ship's place at last: from C draw an *E. b. S. $\frac{1}{2}$ E* rhumb CE=24 miles, and join ED.

In the triangle ABC, where $AB=15$ miles, $\angle ACB=95^\circ 38'$, and the $\angle CBA=45^\circ 00'$; find $AC=10,66$ miles.

In the triangle ABD, where $AB=15$ miles, $\angle ADB=56^\circ 15'$, and the $\angle ABD=73^\circ 08'$; find $AD=17,26$ miles.

In the right angled triangle CAD, where $AC=10,66$, and $AD=17,26$; find $\angle ACD=58^\circ 19'$, $\angle ADC=31^\circ 41'$, and $CD=20,29$ m.

In the triangle CDE, where $CE=24$, $CD=20,29$, and $\angle DCE=14^\circ 49'$; find $\angle CED=52^\circ 42'$, and $DE=6,522$ miles.

ANSWER. The tide set *S. $42^\circ 55'$ W.* and its drift is 6,522 miles.

QUESTION

QUESTION XIII. *A ship running five knots an hour, discovers Scilly lights bearing NE. b. N. distant six leagues, the flood tide being just made, and setting ENE. two miles an hour: Required what course she must steer, and how far by the log, to bring herself five leagues to the south of the Lizard, which lies 11 leagues to the E. b. N. $\frac{1}{2}$ E. of Scilly.*

SOLUTION. Draw SL E. b. N. $\frac{1}{2}$ E. 33 miles, LE S. 15 miles, and SA SW. b. S. 18 miles; join SE, AE: Draw AB ENE. two miles, and on B with BC=5 miles cut AE in C, join BC; draw AD parallel to BC; and ED parallel to AB; then A represents the ship's place at first, S Scilly, L the Lizard, E the ship's place at last, and AD the rhumb and distance she must sail.

In the triangle SLE, where SL=33 miles, LE=15, and the $\angle SLE = 84^\circ 22'$; find $\angle LES = 70^\circ 18'$, $\angle LSE = 25^\circ 20'$, and SE=34,89 m.

In the triangle ASE, where AS=18, SE=34,89, and the $\angle ASE = 104^\circ 02'$; find $\angle SAE = 51^\circ 59'$, $\angle SEA = 23^\circ 59'$, and AE=42,96 m.

In the triangle ABC, where AB=2, BC=5, and $\angle BAC = 18^\circ 14'$; find $\angle C = 7^\circ 11'$.

Now in the triangle ADE, similar to the triangle ABC, are known AE=42,96 miles, $\angle DAE = 7^\circ 11'$, $\angle AED = 18^\circ 14'$, and the $\angle D = 154^\circ 35'$; hence the side AD will be found=31,32 miles.

ANSWER. The ship must sail S. $87^\circ 05'$ E. distance 31,32 miles.

QUESTION XIV. *At six o'clock in the evening a privateer saw a ship directly to windward bearing NE. about three leagues distant, they were both close hauled, on their starboard tacks; the privateer having sailed 18 miles, at nine o'clock the ship bore E. b. N. $\frac{1}{2}$ E. Now the privateer finding he got a-head, would speak with the ship at two o'clock in the morning: Required at what rate the privateer must sail, and at what time tack about, keeping six points from the wind, supposing the other ship does not alter her course and rate of sailing.*

SOLUTION. Six points from the wind at NE. on starboard tacks is NNW.; then in a line AF parallel to a NNW. rhumb take AC=18 m. draw AI NE. in which take AB=9; also BG=3, GI=5, representing the times between six and nine, and nine and two o'clock; draw BE parallel to AF, and through C draw an E. b. N. $\frac{1}{2}$ E. rhumb CD; join DG, draw IE parallel to DG; through E draw EF six points from the wind, and join EC, CB: then the privateer tacking at F, will meet the ship at E.

In the triangle ABC, find $\angle ABC = 82^\circ 46'$, $\angle ACB = 29^\circ 44'$, and CB=16,76.

In the triangle CBD, find BD=12,04, and DC=8,689.

Then BG:GI::BD:DF=20,07 miles, the ship sails from nine to two.

In the triangle CDE, find $\angle C = 81^\circ 31'$, $\angle E = 25^\circ 21'$, and EC=19,42 miles.

In the triangle CEF, find FE=11,76, and FC=25,87 miles.

Now $FE + FC = 37,63$ m. which run in five hours, is $7,12$ m. an hour.
And FC at $7,12$ m. per hour gives 3 h. 37 m. 48 s. after nine o'clock.

ANSWER. The privateer must tack at 12 h. 37 m. 48 s. and sail $7,12$ miles an hour.

QUESTION XV. *Two ships steering between the S. and W. parted company in latitude $20^{\circ} 15'$ N. one going $2\frac{3}{4}$ points more westerly than the other; next day at noon they arrived at two ports in latitude $16^{\circ} 16'$ N. and distant 45 miles: Required the course and distance which each ship sailed after they parted.*

SOLUTION. In an east and west line take $CB = 45$ miles; on CB describe (II. 89) the segment CBA of a circle that shall contain an angle equal to $30^{\circ} 56' = 2\frac{3}{4}$ points; in the meridian take $BH = 59$ miles, the diff. lat.; through H draw HA parallel to CB , meeting the circle CBA in A ; draw AF parallel to HB , meeting CB produced in F , join AB , AC , and from E , the center of the circle CBA , draw EA , EB ; EG parallel to CB , and ED parallel to BH .

In the right angled triangle EBD , where $\angle DEB = (\angle CAB =) 30^{\circ} 56'$, and $DB = 22,5$ miles; find $ED = FG = 37,54$, and $EB = EA = 43,77$ m.

In the right angled triangle AEG ; find $\angle AEG = 29^{\circ} 22'$, and $EG = 38,15$.

In the right angled triangle AFB , where $AF = 59$ miles, $BF = DF (= EG) - DB = 15,65$; find $\angle BAF = 14^{\circ} 51'$, and $AB = 61,06$ miles.

In the right angled triangle AFC , where $AF = 59$, $CF = CB + BF = 60,65$ miles, and $\angle CAF = 45^{\circ} 47'$; find $AC = 84,62$ miles.

ANSWER. $\left\{ \begin{array}{l} \text{The course of one ship is S. } 14^{\circ} 51' \text{ W. dist. } 61,06 \text{ m.} \\ \text{The course of the other is S. } 45^{\circ} 47' \text{ W. dist. } 84,62 \text{ m.} \end{array} \right.$

QUESTION XVI. *Two ships, A and B, both going at the rate of six knots an hour, parted company in the latitude of 45° N. A steering in the NE. and B in the NW. quarter; next day at noon they both arrived at their ports, A in lat. $45^{\circ} 58'$ N. B in lat. $45^{\circ} 36'$ N. and the sum of their departures was 64 miles: At what hour did they part, and what was the course and distance each ship had sailed?*

SOLUTION. Make the departures $FG = 64$ miles, the diff. lat. $FB = 58$, and $GC = 36$ miles; draw BC , and from K , the middle of BC , draw KE at right angles to BC , meeting FG in A , and BF produced in E ; join AC , AB ; then draw AH parallel to FB ; and CD , BH , parallel to FG , meeting AH in I and H .

In the right angled triangle EDC , where $DC = 64$, $DB = 22$; find $\angle DBC = 71^{\circ} 02'$, $\angle DCB = 18^{\circ} 58'$, and $BC = 67,69$ miles: Hence $BK = KC = 33,84$.

In the right angled triangle BKE , where $\angle E = 18^{\circ} 58'$, $KBE = 71^{\circ} 02'$, and $KB = 33,84$ miles; find $BE = 104,1$: Hence $BE - BF = FE = 46,1$ miles.

In

In the right angled triangle EFA, find $FA = 15,84$ miles: Hence $AE = 48,16$.

In the right angled triangle AIC, where $AI = (GC =) 36$, $IC = 48,16$; find $\angle IAC = 53^\circ 13'$, and $AC = 60,13$ miles.

In the right angled triangle AHE, find $\angle BAH = 15^\circ 17'$.

Now AC or $AB = 60,13$ divided by 6 gives $10,02$ hours $= 10$ h. 1 m. 12 s.

ANSWER. { The ships parted at 1 h. 58 m. 48 s. in the morning.
A's course is N. $15^\circ 17'$ W. B's is N. $53^\circ 13'$ E.; dist.
run by each is 60,13 miles.

QUESTION XVII. *Passing by a rock which lies off the mouth of a harbour, the breadth of which is 12 miles, the western point bore NNW. and is nine miles distant from the town; the eastern point bore NE. b. N. and is six miles from the town: Required the distance of the rock from the western and eastern points, and also from the town, which bore N. b. E.*

SOLUTION. With the three given sides, 12, 9, 6, having constructed a triangle where A and C are the western and eastern points of the harbour's mouth, and B the town; make the $\angle ACD = 3$ points, $= \angle$ between the bearings of A and B; also make the $\angle CAD = 2$ points $= \angle$ between the bearings of C and B; through ADC describe a circle, and through D and B draw the right line BF, meeting the circumference of the circle again in F, the place of the rock.

For the $\angle AFD = \angle ACD = 3$ pts.; and $\angle CFD = \angle CAD = 2$ pts. (II. 129)

In the triangle ABC, find $\angle BAC = 28^\circ 57'$, the $\angle BCA = 46^\circ 33'$, and the $\angle ABC = 104^\circ 30'$.

In the triangle ACD, where $\angle ADC = 123^\circ 45'$, $\angle DCA = 3$ points, $\angle DAC = 2$ points; find $DA = 8,018$ miles.

In the triangle ADB, where $AB = 9$, $AD = 8,018$, and $\angle BAD = 6^\circ 27'$; find the $\angle ABD = 41^\circ 05\frac{1}{2}'$: Hence $\angle CBD = 63^\circ 24\frac{1}{2}'$.

In the triangle ABF, find $AF = 10,65$ miles, and $FB = 15,64$ miles.

In the triangle FBC, find $FC = 14,02$ miles.

ANSWER. $FA = 10,65$, $FB = 15,64$, $FC = 14,02$ miles.

QUESTION XVIII. *At night, having cast anchor among a cluster of islands, I observed three lighthouses, A, B, C; A bore NNE. B bore SSE $\frac{1}{2}$ E. and C bore west; the distance from A to B is 94 miles, from B to C 78 miles, and from A to C is 59 miles: Required my distance from each lighthouse.*

SOLUTION. Let ABC be the triangle formed by the distances of the three lighthouses; on CB, CA, describe (II. 89) segments of circles that shall contain the angles included between the bearings of C and B, and of C and A; and the intersection D of these circles, is the point where the ship cast anchor: through the centers H, K, draw HE , BG , at right angles to CB, CA, meeting the circumferences of the circles in E and G; and draw EB, EC; HB, HC; GC, GA; KC, KA; and join KH cutting CD in m.

Now because CD is a chord common to both circles, therefore HK bisects it in m : also, because $\angle CDB$ and $\angle CEB$ together are measured by half the circle (II. 128); therefore $\angle CEB = 180^\circ - \angle CDB$; and for the same reason, the $\angle CGA = 180^\circ - \angle CDA$; therefore the angles CEB , CGA , are known; and (II. 127) so are their equals $\angle CHA = 61^\circ 52\frac{1}{2}'$, $\angle CKb = 67^\circ 30'$.

In the triangle CAB , from the given sides find $\angle CAB = 55^\circ 48'$, $\angle CBA = 38^\circ 44'$, and the $\angle ACB = 85^\circ 28'$.

In the right angled triangle caH , where $ca = 39$ m. $\angle CHA = 61^\circ 52\frac{1}{2}'$; find $CH = 44,22$ miles.

In the right angled triangle cbK , where $CB = 29\frac{1}{2}$ m. $\angle CKb = 67^\circ 30'$; find $CK = 31,93$ miles.

In the triangle KCH , where $KC = 31,93$, $CH = 44,22$, the $\angle KCH = 136^\circ 06'$ ($= \angle KCA + \angle ACB + \angle BCH$); find $\angle CKH = 25^\circ 40'$, and $\angle CHK = 18^\circ 14'$.

In the right angled triangle CHm , where $\angle CHm = 18^\circ 14'$, and $CH = 44,22$ m.; find $cm = 13,84$ miles, which doubled gives $CD = 27,68$ miles.

In the triangle ACD , where $CD = 27,98$ m. $\angle CAD = 25^\circ 40\frac{1}{2}'$, and $\angle ACD = 41^\circ 49\frac{1}{2}'$; find $AD = 42,6$ miles.

In the triangle ADB , where $AB = 94$ miles, $\angle BDA = 129^\circ 22\frac{1}{2}'$, $\angle DAB = 30^\circ 07\frac{1}{2}'$; find $DB = 61,03$ miles.

ANSWER. The distance from D to $\left\{ \begin{array}{l} A \text{ is } 42,6 \text{ miles.} \\ B \text{ is } 61,03 \text{ miles.} \\ C \text{ is } 27,68 \text{ miles.} \end{array} \right.$

QUESTION XIX. *In latitude $48^\circ 50'$ N. we were attacked by a privateer, who upon receiving our broadside lay to, and we stood away NNW.; some time after the privateer bore away NE. b. N. and two hours after, he having by our estimation run ten miles, was seven miles directly east of us. Now by our account we had sailed four leagues since the action, and the tide all the time had run two miles an hour: Required the setting of the tide, the time the privateer lay to, our rate of sailing, and each ship's direct course and distance.*

SOLUTION. Suppose the action at A , then parallel to the NNW. and NE. b. N. rhumbs, draw $AB = 12$ m. $AC = 10$ m. and join BC ; through C draw $CD = 7$ miles due west; join BD , and in this line produced take $DI = 4$ miles, the tide's drift in two hours; draw CF parallel and equal to DI ; through F draw a west line FG , meeting BI in I , and a meridian through A , in G ; and draw AF , AI , which represent the runs of the two ships, F being the place of the privateer, when she was seven miles east of the other ship, then at I .

In the triangle AEC , where $AB = 12$, $AC = 10$, and $\angle BAC = 56^\circ 15'$; find $\angle ACB = 71^\circ 31\frac{1}{2}'$, $\angle ABC = 52^\circ 13\frac{1}{2}'$, and $BC = 10,52$ miles.

In the triangle BCD , where $BC = 10,52$ m. $CD = 7$ m. $\angle BCD = 15^\circ 16\frac{1}{2}'$ ($71^\circ 31\frac{1}{2}' - 56^\circ 15'$); find $\angle BDC = 138^\circ 40'$, $\angle DBC = 26^\circ 04'$, and $BD = 4,197$ miles, which is the tide's run while the privateer lay by. In

In the triangle ACF , where $CA=10$ m. $CF=4$ m. and $\angle ACF=82^\circ 25'$ ($=\angle DCF-\angle DCA$); find $\angle AFC=74^\circ 52\frac{1}{2}'$ $\angle CAF=22^\circ 42\frac{1}{2}'$. and $AF=10,27$ miles, the distance sailed by the privateer.

In the right angled triangle AGF , where $AF=10,27$, the $\angle FAG=(\angle GAC+\angle CAF=) 56^\circ 27\frac{1}{2}'$ find $AG=5,675$, and $GF=8,561$ miles.

In the right angled triangle AGI , where $AG=5,675$, $GI=(GF-(IF=) 1,561$; find $\angle GAI=15^\circ 23'$, and $AI=5,886$ miles.

Now $4,197$ m. divided by 2 m. per hour, gives $2,098$ h. $=2$ h. 5 m. 52 f.

ANSWER. $\left\{ \begin{array}{l} \text{The privateer lay by } 2 \text{ h. } 5 \text{ m. } 52 \text{ f. nearly.} \\ \text{The tide sets S. } 48^\circ 40' \text{ E.} \\ \text{The privateer sailed N. } 56^\circ 27' \text{ E. distance } 10,27 \text{ miles.} \\ \text{The other ship sailed N. } 15^\circ 23' \text{ E. distance } 5,886 \text{ miles.} \end{array} \right.$

QUESTION XX. *From the ports A, B, C, lying under the same parallel of latitude, B being 60 miles, and C 160 miles to the east of A, three ships sail toward the NW. quarter and meet together, B having sailed two points, and C $3\frac{1}{2}$ points farther from the meridian than A had: Required the course and distance each ship has run.*

SOLUTION. In an east and west line CD , take $CA=160$ m. $AB=60$ m. make the angle $ACE=2$ points $=22^\circ 30'$, the angle $CAE=1\frac{1}{2}$ points $=16^\circ 52'$; and join EB .

Through the points AEC describe a circle, cutting the line EB produced in H , and join HA , HC .

Now $\angle AHE=\angle ACE$; and $\angle BHC=\angle BAE$. (II. 129)

Therefore ships sailing from A, B, C, and meeting in H, their course will differ by the quantities proposed.

For drawing a meridian HD , the angles DHA , DHB , DHC , will respectively represent the angles which the ship's courses make with the meridian.

In the triangle ACE , where $AC=160$ miles, $\angle EAC=1\frac{1}{2}$ points, $\angle ECA=2$ points, and $\angle AEC=12\frac{1}{2}$ points; find the side $EC=73,21$ miles.

In the triangle BCE , where $BC=100$ m. $CE=73,21$, and the included $\angle BCE=22^\circ 30'$; find the angle $CEB=116^\circ 37'$, and $\angle CBE=40^\circ 53'$.

Hence $\angle ABH=40^\circ 53'$ (II. 93); the $\angle HAB=116^\circ 37'$.

In the triangle AHB , where $AB=60$, and all the angles are known, find $HA=102,6$ miles, and $HB=140,2$ miles.

In the triangle AHC , where $AC=160$, and all the angles are known, find $HC=225,5$ miles.

ANSWER. $\left\{ \begin{array}{l} \text{A's course is N. } 26^\circ 37' \text{ W. distance } 102,6 \text{ miles.} \\ \text{B's course is N. } 49^\circ 07' \text{ W. distance } 140,2 \text{ miles.} \\ \text{C's course is N. } 65^\circ 59' \text{ W. distance } 225,5 \text{ miles.} \end{array} \right.$

SECTION X.

Of the surveying of Coasts and Harbours.

From what has been already said in the preceding sections, an intelligent reader would see how the business of taking the bearings of part of a coast, and of plotting or delineating it, might be done. But as there are some particulars, which can be gained only by experience in the art of surveying, it will not be improper to apprize the learner concerning them, to qualify him to go more readily to work.

52. *To take the Draught of part of a Coast in sailing along it.*

1st. Having brought the ship to a convenient place, from which the principal points of the coast, or bay, may be seen, either cast anchor, if it is convenient, or *lie to* as steady as possible; or if the coast is too shoal, let the observations and measures be done in a boat. Then while the vessel is stationary in that situation, take the bearings in degrees of such points of the coast, as form the most material projections, or hollows, with the azimuth compass; write down these bearings, and make a rough sketch of the appearance of the coast, observing carefully to mark the points, the bearings of which had been taken, with letters, for the sake of reference.

2d. Then let the ship or boat run in a direct line, which must be very carefully measured by the log, or otherwise, one, two, or three miles, more or less, until she comes into a situation from which the same points before observed can be seen again. There let the vessel lie steady, as at the foregoing station, and observe again the respective bearings in degrees of the same points, which are also to be written down; and a rough sketch of the coast should also be taken from this station. But while the vessel is running the *base line* from station to station, a more accurate drawing of the appearance of the coast should be made.

3d. *To map these observations.* In some convenient part of a sheet of paper describe a circle, draw the magnetic meridian, lay off the several bearings taken from the first station, and let them be numbered 1, 2, 3, &c. on the outside of the circle: lay down also the several bearings taken from the second station, let these be numbered 1, 2, 3, &c. on the inside of the circle, observing that the bearings of the same points are numbered with the same figures.

4th. Draw a line to express the ship's run both in length and course; and from that end of the line expressing the first station, draw lines parallel to the respective bearings taken from that end, and marked on the outside of the circle: also from the other end, draw lines parallel to the bearings taken at that end, and noted on the inside of the circle; mark the intersection of each pair of lines, directed to the same point, with the number annexed to their bearing; and through the intersections, so marked, draw, by hand, a curved line, observing to wave the line in and out, as near as can be, like the bending of the coast itself. Lastly, Set off the variation of the compass from the north end of the magnetic meridian toward the right hand, if it be east, or toward the left hand, if it be west, and draw the true meridian through that point and the center of the circle.

5th. Again.

5th. Against each part draw the appearance of the elevated, or low ground, as marked in the sketches, distinguishing rocks, cliffs, high-land, low-land, sand-hills, &c. If there are any currents, or eddies, express them in their proper places by darts, or arrows, the points being turned that way the current sets. Put in the several soundings at low water in small figures, distinguishing whether they are fathoms or feet; shew the time of high-water on the full and change days by Roman figures, and tell the rise in feet. Put in a compass, and a scale of miles or leagues, such as the vessel's run was laid down by; add the name of the place, the coast, and the latitude and longitude, as true as can be obtained.

6th. If there are shoals, or sands, on the coast, let them be taken by a boat sailing round them, and keeping an account of the courses, distances, and soundings. But to put them in the draught, the boat must take the bearings of two points on the coast, the bearings of which have been taken from the ship, from some part of each sand or shoal so sailed round. Or, the bearing of the boat at some part of the shoal, or of some beacon in that place, must be taken by the ship at each of the stations where she took the bearings of the shore; for by either of these means one point of the sand being obtained, the rest of it can be laid down from the boat's account.

7th. If the coast to be surveyed is a bay or harbour, winding in such a manner that all its principal points cannot be seen at two stations, let as many bases, or lines, be run and measured exactly, as may be found necessary; observing that these several bases run join to one another in the nature of a traverse, and that each new set of objects, or points, observed, be taken from two stations at the end of a known distance. Or, look out for three or more remarkable objects on shore, which lie as far out of a right line as possible, and may be seen from every part of the bay or harbour which is to be surveyed. From any convenient station let the bearing of one of these objects be taken with the compass, and the angles which are subtended by this and each of the others, be observed with Hadley's quadrant. Let the ship run from this station, in a direct line, as far as the nature of the place will admit of, measuring the distance run by the log. Bring the ship to, or come to an anchor, and let the angles which these objects subtend be again measured with the quadrant, and the bearing of that object be set with the compass, which was set before. By these means, the situations of the objects on shore will be had with respect to one another, and to the base line; after which the position of any point may be obtained, by measuring the angles subtended at that point, by any two pairs of them, with Hadley's quadrant.

8th. If any particular parts of the harbour cannot be conveniently seen from either of the stations, take the boat into those places, and having well examined them, make sketches of them, estimating the lengths and breadths of the several inlets, either by the rowing, or sailing of the boat, taking as many bearings, soundings, and other notes, as may be thought necessary; then annex these particular views in their proper places in the general draught.

9th. If there are any dangerous sands, or rocks, besides inserting them in their proper places, there should be a double line drawn through that point and one or more objects ashore; and for this purpose, chuse a church,

church, mill, house, noted tree, a cliff, or any other remarkable thing that can be distinctly seen at sea, and which can be brought to bear in the same right line with the point to be avoided. But if that point is under water, there must be two land-marks brought to bear with the danger, in the same right line; and also two others which are in a direction, as nearly at right angles as can be to the former two; and that those land-marks may be put down in their proper places in the chart, their bearings must also be taken from two of the ship's stations.

10th. It should be remarked in the draught what places are unfit for anchorage, and what are fit, by writing *rocky ground*, *foul anchorage*, *good anchorage*, &c.; and in the latter to draw the figure of an anchor. Also, if there is any particular channel more convenient to sail through than another, it is to be pointed out by lines drawn to its entrance from two or more noted marks ashore.

The foregoing method of surveying a coast supposes in general, that it is taken by a ship in her passage along, not having an opportunity of going ashore. But when the circumstances will permit the measures and observations to be made on land, the survey can be taken more accurately than on the water.

53. *To survey a Harbour by Observations on Shore.*

1st. Make an eye-draught of the place to be surveyed; and in going round its coasts, fix station staves, or straight poles, tall enough to be seen at a considerable distance, in the most remarkable points and bendings of the shore; but if at any of those places there is a noted tree, house, or any other remarkable thing, that object may serve instead of a station staff; and it will be convenient to black the staves, and tie a piece of white bunting to the top of each. Then in the eye-draught put letters at the noted points, or marks, for the sake of distinction.

2d. Chuse the most extensive and level spot of ground you can meet with, to measure your base line on, which should not be less than a tenth part of the distance of the two extreme objects which are to be observed; and let the direction of the measured base line be such, that as many of the stations as possible may be seen from each end of it. The bearing, or position, of this base, must be well determined in degrees and minutes; and its length accurately measured, either by a measuring chain, or by a piece of log line.

3d. From each end of the base, observe with Hadley's quadrant, the angles subtended between the other end and each of the station staves, or objects which had been before remarked at each point or bending of the coast; and write them down orderly in your book, or mark them on the eye-draught.

4th. Then these measures and angles being plotted, or laid down, will give the most conspicuous points of the shore; the intermediate spaces are to be filled up from the sketches of them made on the spot, as in 8th of Article 52.

5th. But if any of these objects should spread on either hand so far beyond the limits of the base, that at either end the other end and those objects or staves should appear nearly in the same direction, or to make angles not exceeding 10 degrees; or, if some of the remarked objects can

can be seen only from one end of the base; then let the bearings of such objects be taken from a place, the position of which has been determined from both ends of the measured base: or, if there are several remarked objects which cannot be seen from either end of the base line, let the bearings of such objects be taken from each of two points, the positions of which have been taken from both ends of the base: or, it may on some occasions be proper to chuse another place, on which another base of a convenient length may be measured, and from the extremities of which the ends of the first base may be seen; and also, as many as can be of the remaining objects which lay too oblique for the first base, or which could not be seen from it: in such manner proceed until the bearings are taken of all the points that are judged necessary for completing the survey of the harbour.

If a base of a sufficient length cannot be measured in one right line, it may be taken in two adjoining lines, as the two sides of a triangle; the included angle being accurately taken, and the bearing of either line.

The positions of objects taken by a magnetic compass being liable to great uncertainties, as is well known to those who have had any experience, especially at sea; the mariner has therefore been directed, in the foregoing instructions, to take as many of the angular positions as may be, by the Hadley's quadrant, the description and use of which will be given in the IXth Book.

54. When the outlines, or limits of an harbour, bay, road, &c. are delineated by the preceding precepts; the appearances of the shores, with the adjacent remarkable objects, correctly drawn; a compass with the variation and scale properly fitted to the plan; the isles, rocks, sands, &c. marked in their proper places; the setting and drift of the currents, and tides; the times of high-water on the days of new and full moon, with the rise of water at those times, and whether whole tide, or tide and part; the best anchoring places, with their soundings at low water, and the winds open to them; the best track, with the soundings all the way to those anchoring-places; the proper sailing marks to avoid dangers; the winds, if there are any troublesome ones, which prevail, and at what seasons; the places where fresh water can be got, and the time in which a boat's crew can fill a number of hogheads at those places; the name of the place, the country in, on what sea, the latitude and longitude; a sketch of the appearance the place makes at sea upon a known rhumb, and at an estimated distance; and whatever else a judicious seaman shall think proper to insert; then is the plan fit for all nautical purposes. But as it is usual to embellish such drawings with proper colours, the following observations may be useful to beginners.

55. A draughtsman should be furnished with some, if not all, of these particulars, *viz.* 1st. Black-lead pencils: 2d. One pair of hair pencils, with the quill about the size of a common pen, and the hairs not shorter than $\frac{1}{2}$ an inch, nor longer than $\frac{2}{3}$ inch; another pair or two of a size or two smaller; they should all draw to a fine point when wetted; and that wet point be drawn through the margin of the flame of a candle, to take off the ends of straggling hairs, if there are any: 3d. A marble of five or six inches square, and about $\frac{1}{4}$ inch thick, in which are four, or six, or more little round cavities, or cells of about $1\frac{1}{4}$ inch diameter,

diameter, and $\frac{1}{4}$ inch deep, to put liquid colours in when using; or, for want of a marble, a few horse-muscle, or such like, shells: 4th. A cake of good Indian ink: 5th. A little paper of carmine, which is a fine red colour: 6th. A piece of prepared indigo, which is a blue: 7th. A piece of prepared yellow: 8th. A piece of a sap-green: 9th. A piece of Spanish liquorice, or some liquid brown, made by a strong solution of tobacco in boiling water: 10th. A small vial of distilled verdigrise, which is a fine sea-green: 11th. Some gum Arabic dissolved in water. These particulars are to be had at colour shops: where the colours in lumps, or liquids, are generally prepared with a sufficient quantity of gum in them; but those in powders must have a pencilful or two of gum water put to them, when they are used.

The colours in lumps are best used by rubbing one end of the lump gently in a cell in the marble (or on a tile) till as much is wore off as is judged necessary for the present use; and it is best to rub off fresh colour as it is wanted, and not to have too much at a time. If the colour first rubbed up is too strong, as it generally is (unless for finishing touches) put one or two pencils full of that colour into another cell, and lighten it with one or more pencils full of water; remove some of this second colour into a third cell, and lighten this with water; and so to a fourth cell; by this four different tints of that colour will be had, which will be found quite sufficient in the most finished piece; in most cases two tints will do.

In the using of liquid colours the pencil should be well wetted with the colour, and then gently drawn across the edge of the cell, to bring the pencil to a point, and free it of some of the colour; for the pencil should not be quite full, unless it be to cover a large spot of the drawing.

56. When a person, unaccustomed to the use of colours, begins to work with them, he may acquire by degrees a facility in laying them well on paper. Thus, with a black-lead pencil draw two parallel lines at about $\frac{1}{4}$ inch apart, and with the lightest of the aforesaid tints (suppose of Indian ink) let him try to colour the space between these lines; and repeat the trial with other lines, until he finds he can cover the space with an uniform tint, and keep exactly between the lines. Let him try in like manner with all the tints gradually to the deepest (which is about as black as good writing ink) and the most difficult to use; and when he finds he can succeed in all the tints, and his hand is accustomed to keep the colour exactly to a line, which he may acquire in a few days, he may proceed thus: With a pair of pencils fitted on a stick, one for colour, and the other for fair water, let him lay a tint close to a single line, and soften off the other margin with the water-pencil; let him try to do this in several examples, some on one side, and some on both sides, of the colour, taking of different tints, until he finds that he can succeed so, that the colour shall, from the deepest, gradually become fainter and fainter, until it loses itself in the whiteness of the paper; observing, 1st. not to lay on a tint longer than $1\frac{1}{2}$ or 2 inches, before the water-pencil is applied to soften its margin, lest the colour should dry too fast: 2d. not to have the water-pencil too wet, lest it run into the tint too much: 3d. at each length the water-pencil is used to, let its point be stroked on the hand, or on a waste-paper, to take off the colour it had imbibed in washing that length; otherwise the next length might be of a different tint.

The foregoing observations being well attended to, will enable a beginner to work properly with colours, in plans. But it must be confessed, that half an hour employed in seeing these operations performed by an artist, will furnish more knowledge in these matters, than can be drawn from a multitude of verbal instructions only.

57. The young artist knowing how to use his colours, and graduate their tints, may proceed to colour the plans of harbours, and their coasts, thus:

The shores on the land-side are to be shaded with Indian ink; the breadth of the tint being within the limits of about $\frac{1}{8}$ and $\frac{1}{4}$ of an inch, and laid on at three times; viz. 1st. A light tint laid close to the shore, with the margin on the land-side softened off: 2d. A deeper middle tint, laid also close to the shore, but of a less breadth than the former, and the inside margin also softened off within the first washing: 3d. A fine line traced on the said shore, with a hair pencil charged with the deepest tint, and not softened on either side.

The shores on the water-side are to be shaded with distilled verdigrise; the breadth of the tint about $\frac{1}{4}$ inch, and laid on at twice; for the first tint, about half water and half colour, laid close to the shore, and the water-side margin washed; the second tint of verdigrise only, narrower than the former, laid close to the shore, and not washed.

Sands, dry at low water, to be covered pretty thick with fine black points (see figures 12, 16, 18, 20, in Plate IX.) the sand coloured with brown, and the borders on the water-side shaded with verdigrise washed or softened.

The plans of buildings on the land to be coloured with a light tint of carmine, and the limit, on the inside, touched round with a deeper tint.

Fresh waters to be expressed by a colour of half verdigrise and half fair water, shaded with a light tint of indigo; or with a tint of indigo alone, of a light sky-colour, interspersed with fine streaks of white.

Green colours of various tints may be made with sap-green, yellow and blue rubbed together, with a pencil-full of verdigrise among them; and with such colours woods and grass lands may be expressed, when properly broken in with trees, bushes, and little irregular dashes with Indian ink.

Arable or ploughed land is expressed by covering the spot in the drawing with a kind of broken parallel lines, done by a hair pencil dipt in a brown or clay colour.

Muddy shores at low-water are shewn by laying on a middling tint of Indian ink, and laying over that a tint of light verdigrise.

The drawing and colouring of rocky shores, steep banks, hills, marshy ground, and the manner of breaking the ground in plans, &c. are best gained from examining a coloured plan done by a proper proficient; but where that is wanting, a pretty good taste may be gained by consulting printed plans and views, such as are in Lord Anson's voyage round the world.

Sea-

Sea-draughts taken according to the preceding precepts, and neatly drawn and coloured, besides the real use they may be of, cannot fail to recommend the young mariner, who surveys and constructs them, to the notice of his superiors.

SECTION XI.

To estimate Distances.

Besides the method of finding the distances of remote objects by trigonometrical computations, there are two other means which may be usefully applied when the former cannot; and these are, the *motion of sound*, and the *curvature of the earth*.

58.

Of the Motion of Sound.

It is a well known observation, that the noise or sound arising from any blow or shock, made at a distance, is always heard some time after the stroke is seen, or known to be given; and hence it is generally concluded, that the seeing of any act done within view is instantaneous, but that sound travels at a perceptible rate.

Some of the most eminent philosophers, judging that the knowledge of the flight of sound might be of use on various occasions, have been at extraordinary pains and expence to measure the rate at which it moved; and the result of their experiments, particularly of those which were best conducted, is as follows.

1st. That the velocity of sound is the same, whether by sea or by land, in dry or in rainy weather, by day or by night, in winter or summer.

2d. That sound, whether more or less strong, flies with the same swiftness. For, by experiments, a cannon fired with a half-pound charge of powder was heard at about the distance of $17\frac{1}{2}$ miles in the same time after the flash was seen, as it was when fired with a charge of 6 lb.

3d. That the times in which sound is heard are proportional to the distance; that is, at a double distance it is heard in twice the time; at a triple distance in thrice the time, &c.

4th. That sound flies quicker or slower by just the velocity of the wind, according as it blows with or against the motion of the sound.

5th. That sound travels at the rate of about 1142 feet, or 380 yards in one second of time; so that

Sound moves in 1 second, 1142 feet, or 380 yards.

1 minute

22840 yards, or about 13 miles.

Which is about a miles in 4.6 seconds, or about a league in 14 seconds.

But sea miles are to land miles nearly as 7 to 6.

(V. 73.)

Therefore sound runs a sea league in about 12 seconds of time.

It is a common observation, that persons in good health have about 75 pulsations, or beats, of the artery at the wrist in a minute.

59. There-

59. Therefore in 75 pulsations found flies about 13 land miles, and about $11\frac{1}{2}$ sea miles; which is about one land mile in six pulses, and about one sea mile in near seven pulses, or a league in 20 pulses.

And hence the distance of objects may be found, by knowing the time which sound takes to move from those objects to an observer.

EXAMPLE. Upon seeing the flash of a gun at sea, I counted 56 beats of the pulse at my wrist before I heard the report: How far was that gun from me?

Now 56 divided by 20 gives 2,8 leagues, or about eight miles.

60. To find the Course steered by a Ship seen at a distance.

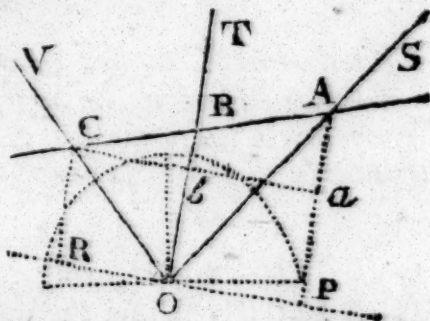
A ship lying to (at O ,) may discover the course (AC ,) which a vessel seen at a distance is going on; by taking, at two known intervals of time, three bearings (OS , OT , OV) of that vessel; thus:

In a line POR , drawn at right angles to the middle bearing OT , take OP , OR , as the given intervals of time, in minutes, taken from any scale of equal parts; and through P , R , draw lines parallel to OT , cutting OS , OV , in A , C .

Then a right line drawn through A and C , cutting OT in B , will shew the position, or the course, that vessel was sailing.

For drawing ca parallel to RP , and cutting PA , OB , in a , b ; then ab , bc , equal to PO , OR , are as the times; and so are the lines AB , BC , by similar triangles.

Although by this method the apparent course may be determined, and also the relative distances at any proposed times; and among others, the nearest or least distance; yet the absolute distances are not hence to be found; and if the observing ship should change its place in the mean time, the position of AC will become uncertain.



61. Of the Curvature of the Earth.

Most persons know, that if they are raised above the surface of the adjacent land or water, they can see not only distant objects that lie on that surface better, but also see those which are more and more remote, as they advance higher. The irregularity of the surface of the land will not be subjected to any one rule, that will give the distance to which objects may be seen at different elevations; but at sea, where there is generally an uniform curvature of the surface of the water, the spherical figure of the Earth being admitted, those distances may be easily computed.

62. Let (see fig. 12. Pl. XIV.) the eye at E be raised the height ES above the surface s of the water; then it will see an object at f on the surface, in the tangent ef , which is the distance of that object from the eye.

Now

Now in the triangle Efc , right angled at f , there are known the side cf =semidiameter of the Earth, and the side CE equal to the semidiameter CS increased by SE the height of the eye: to find the tangent Ef .

$$\begin{aligned}\text{Then (II. 113.) } Ef &= \sqrt{CE^2 - Cf^2} = \sqrt{CS + SE^2 - Cf^2} \\ &= \sqrt{2CS + SE \times SE}.\end{aligned}$$

That is, *To the Earth's diameter add the height of the eye, multiply the sum by that height; then the square root of the product is the distance, at which an object on the surface of the water can be seen by an eye so elevated.*

And by this Rule was the table at Article 65 computed, the diameter of the Earth being taken at 41798117 feet, according to Sir Isaac Newton's numbers.

This table may be usefully applied to estimate the distance of an object at sea, the elevation of that object above its horizon being known.

EXAMPLE I. *Sailing towards a headland, on which is a lighthouse, elevated 600 feet above the surface of the water, we saw the lights at night just appearing in the horizon: How far were we at that time distant from the lighthouse?*

Seek in the table at Article 65 for 600 feet in the column signed *height in feet*, and right against it, in the column signed *distance in miles*, stands 29,994; so that the distance may be reckoned about 30 miles.

EXAMPLE II. *Being walking on a sandy beach, in company with some merchants who were looking out for a vessel which was then expected, and whose top-gallant mast was 140 feet above the surface of the water, we observed, with a telescope, a ship's vane just appearing in the horizon: How far off was that ship, supposing it the vessel expected?*

ANSWER. Against 140 feet, the height, stands 14,448; that is, her distance is $14\frac{1}{2}$ miles.

63. Here is no allowance made for the height of the eye above the horizon; but it is obvious, that the higher the eye, the farther it can see. Now as objects are seen in a straight line, and that line is a tangent to the earth's surface, therefore it follows, that *to find the distance of two elevated objects, when the right line joining them touches the surface of the Earth, between those objects seek the distance answering to each height, and the sum is the distance sought.*

Thus in Example II. suppose the eye is raised six feet above the water's edge, it can see an object on the surface 2,999, or three miles off; this distance being added to the $14\frac{1}{2}$ miles, makes the distance of the ship to be $17\frac{1}{2}$ miles.

EXAMPLE III. *A man being on the main-top-gallant mast of a man of war, 200 feet above the water, sees a 100 gun ship she had engaged the day before, hull to: How far were those ships distant?*

A ship of 100 guns, or a first rate man of war, is about 60 feet from the keel to the rails; from which deduct about 20 feet for the draught of water, leaves 40 feet for the height of her quarter above water: now a ship is seen *hull to*, when her upper works just disappear.

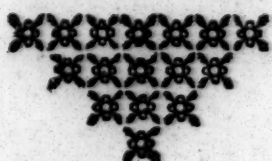
Then 200 feet high give
And against 40 feet stand

17,316 miles.
7,744 miles.

Their sum, which is

25,060 miles, is their distance.

64. It might perhaps hereafter be found useful to mariners, could a list of the most considerable lighthouses, and other elevated objects in different parts of the world, be obtained, together with their heights above the water. For as some of these objects are so high as to be seen at the distance of 30 or 40 miles, and even more; and as their distances upon being first seen could be known near enough by the table at Art. 65. were their heights known; therefore such a list might, on several occasions, not only give much satisfaction to a seaman, but even become of great use to know his distance from those objects, as he could thereby know how to increase or slacken sail in order to save his tide, or other emergency; also he would know better how to lay down the distances of rocks or shoals that lie off a coast, &c. But as such a list is not easy to be come at, unless skilful mariners would be at the trouble of procuring such as occurred to them in their voyages, and on their return communicate them to some public body; therefore the curious in those matters must be contented at present with what is here already said.



Art. 65. *A TABLE for finding the Distance of observed terrestrial Objects at Sea.*

Height in Feet	Dist. in miles.	Height in feet	Dist. in miles.	Height in feet	Dist. in miles.	Height in feet	Dist. in miles.	Height in feet	Dist. in miles.
1	1,224	53	8,914	240	18,969	760	33,756	2250	58,083
2	1,732	56	9,163	245	19,165	780	34,197	2300	58,725
3	2,121	59	9,405	250	19,360	800	34,633	2350	59,360
4	2,449	62	9,641	255	19,553	820	35,063	2400	59,988
5	2,730	65	9,872	260	19,743	840	35,488	2450	60,609
6	2,999	68	10,097	265	19,932	860	35,908	2500	61,225
7	3,239	71	10,317	270	20,119	880	36,323	2550	61,834
8	3,465	74	10,533	275	20,305	900	36,734	2600	62,437
9	3,673	77	10,745	280	20,489	920	37,140	2650	63,035
10	3,872	80	10,952	285	20,671	940	37,541	2700	63,628
11	4,061	83	11,156	290	20,851	960	37,938	2750	64,215
12	4,242	86	11,355	295	21,030	980	38,332	2800	64,794
13	4,415	89	11,552	300	21,208	1000	38,721	2850	65,370
14	4,581	92	11,745	310	21,558	1030	39,297	2900	65,941
15	4,742	95	11,932	320	21,903	1060	39,866	2950	66,507
16	4,898	98	12,121	330	22,243	1090	40,426	3000	67,068
17	5,048	101	12,306	340	22,578	1120	40,978	3050	67,625
18	5,195	104	12,487	350	22,907	1150	41,524	3100	68,177
19	5,338	107	12,666	360	23,232	1180	42,062	3150	68,725
20	5,476	110	12,842	370	23,553	1210	42,593	3200	69,268
21	5,611	113	13,016	380	23,869	1240	43,118	3250	69,807
22	5,743	116	13,188	390	24,181	1270	43,636	3300	70,342
23	5,873	119	13,357	400	24,489	1300	44,149	3350	70,873
24	5,999	122	13,525	410	24,793	1330	44,655	3400	71,400
25	6,122	125	13,690	420	25,094	1360	45,156	3450	71,923
26	6,243	128	13,853	430	25,391	1390	45,651	3500	72,443
27	6,362	131	14,015	440	25,684	1420	46,141	3550	72,958
28	6,479	134	14,174	450	25,974	1450	46,629	3600	73,470
29	6,594	137	14,332	460	26,261	1480	47,106	3650	73,979
30	6,709	140	14,488	470	26,545	1510	47,581	3700	74,484
31	6,817	143	14,642	480	26,826	1540	48,052	3750	74,985
32	6,928	146	14,795	490	27,104	1570	48,517	3800	75,484
33	7,034	150	14,995	500	27,379	1600	48,979	3850	75,979
34	7,140	155	15,244	510	27,652	1630	49,436	3900	76,471
35	7,244	160	15,488	520	27,922	1660	49,889	3950	76,959
36	7,347	165	15,728	530	28,189	1690	50,338	4000	77,445
37	7,448	170	15,965	540	28,454	1720	50,782	4050	77,927
38	7,548	175	16,198	550	28,716	1750	51,223	4100	78,407
39	7,647	180	16,427	560	28,976	1780	51,661	4150	78,884
40	7,744	185	16,654	570	29,233	1810	52,094	4200	79,355
41	7,840	190	16,878	580	29,489	1840	52,524	4250	79,829
42	7,935	195	17,098	590	29,742	1870	52,951	4300	80,297
43	8,029	200	17,316	600	29,994	1900	53,374	4350	80,762
44	8,122	205	17,531	620	30,489	1930	53,793	4400	81,225
45	8,214	210	17,744	640	30,976	1960	54,210	4450	81,685
46	8,305	215	17,955	660	31,457	2000	54,761	4500	82,143
47	8,394	220	18,162	680	31,930	2050	55,441	4550	82,598
48	8,483	225	18,366	700	32,396	2100	56,113	4600	83,051
49	8,570	230	18,569	720	32,855	2150	56,777	4650	83,502
50	8,658	235	18,770	740	33,309	2200	57,434	4700	83,949

66. A TRAVERSE TABLE

To every Point and Quarter Point of the
Compass or Horizon :

In FOUR PAGES.

AND ALSO,

67. A TRAVERSE TABLE

To every Degree and Quarter Degree
of the Compass or Horizon :

In FORTY-FIVE PAGES.

TRAVERSE TABLE, 66.

Distance	0 Point						1 Point										2 Points		Distance
	$\frac{1}{4}$		$\frac{1}{2}$		$\frac{3}{4}$		0		$\frac{1}{4}$		$\frac{1}{2}$		$\frac{3}{4}$		0				
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.			
1	1.00	0.05	0.99	0.10	0.99	0.15	0.98	0.20	0.97	0.24	0.96	0.29	0.94	0.34	0.93	0.38	0.92	0.42	1
2	2.00	0.10	1.99	0.20	1.98	0.29	1.96	0.39	1.94	0.49	1.91	0.58	1.88	0.67	1.85	0.77	1.83	0.86	2
3	3.00	0.15	2.99	0.29	2.97	0.44	2.94	0.59	2.91	0.73	2.87	0.87	2.82	1.01	2.77	1.15	2.70	1.29	3
4	4.00	0.20	3.98	0.39	3.96	0.59	3.92	0.78	3.88	0.97	3.83	1.16	3.77	1.35	3.70	1.53	3.62	1.71	4
5	4.99	0.25	4.98	0.49	4.95	0.75	4.90	0.98	4.85	1.21	4.78	1.45	4.71	1.68	4.62	1.91	4.53	2.14	5
6	5.99	0.29	5.97	0.59	5.93	0.88	5.89	1.17	5.82	1.46	5.74	1.74	5.65	2.02	5.54	2.30	5.44	2.58	6
7	6.99	0.34	6.97	0.66	6.92	1.03	6.87	1.37	6.79	1.70	6.70	2.03	6.59	2.36	6.47	2.68	6.35	3.00	7
8	7.99	0.39	7.96	0.78	7.91	1.17	7.85	1.56	7.76	1.94	7.66	2.32	7.53	2.69	7.39	3.06	7.25	3.43	8
9	8.99	0.44	8.96	0.88	8.90	1.32	8.83	1.76	8.73	2.19	8.61	2.61	8.47	3.03	8.32	3.44	8.17	3.85	9
10	9.99	0.49	9.95	0.98	9.88	1.47	9.81	1.95	9.70	2.43	9.57	2.90	9.42	3.37	9.26	3.82	9.10	4.28	10
11	10.99	0.54	10.95	1.08	10.88	1.61	10.79	2.15	10.67	2.67	10.53	3.19	10.36	3.71	10.16	4.21	10.00	4.70	11
12	11.99	0.59	11.94	1.18	11.87	1.76	11.77	2.34	11.64	2.92	11.48	3.48	11.30	4.04	11.09	4.59	10.91	5.10	12
13	12.98	0.64	12.94	1.27	12.86	1.91	12.75	2.54	12.61	3.16	12.44	3.77	12.24	4.38	12.01	4.97	11.77	5.64	13
14	13.98	0.69	13.93	1.37	13.85	2.05	13.73	2.73	13.58	3.40	13.40	4.06	13.18	4.72	12.94	5.31	12.69	5.94	14
15	14.98	0.74	14.93	1.47	14.84	2.20	14.71	2.93	14.55	3.64	14.35	4.35	14.12	5.05	13.86	5.74	13.60	6.41	15
16	15.98	0.79	15.92	1.57	15.83	2.35	15.69	3.12	15.52	3.89	15.31	4.64	15.06	5.39	14.78	6.12	14.50	6.88	16
17	16.98	0.84	16.92	1.67	16.82	2.49	16.67	3.32	16.49	4.13	16.27	4.93	16.01	5.73	15.71	6.51	15.41	7.34	17
18	17.98	0.88	17.91	1.76	17.81	2.64	17.65	3.51	17.46	4.37	17.22	5.22	16.95	6.06	16.63	6.88	16.29	7.77	18
19	18.98	0.93	18.91	1.86	18.79	2.79	18.64	3.71	18.43	4.62	18.18	5.51	17.89	6.40	17.55	7.27	17.19	8.24	19
20	19.98	0.98	19.90	1.96	19.78	2.93	19.62	3.90	19.40	4.86	19.14	5.81	18.83	6.74	18.48	7.62	18.11	9.20	20
21	20.98	1.03	20.90	2.06	20.77	3.08	20.60	4.10	20.37	5.10	20.10	6.10	19.77	7.07	19.40	8.04	19.02	10.24	21
22	21.97	1.08	21.89	2.16	21.76	3.23	21.58	4.29	21.34	5.35	21.05	6.39	20.71	7.41	20.33	8.42	19.95	11.30	22
23	22.97	1.13	22.89	2.25	22.75	3.37	22.56	4.49	22.31	5.59	22.01	6.68	21.65	7.75	21.25	8.80	20.87	12.40	23
24	23.97	1.18	23.88	2.35	23.74	3.52	23.54	4.68	23.28	5.83	22.97	6.97	22.60	8.08	22.17	9.18	21.73	13.54	24
25	24.97	1.23	24.88	2.45	24.73	3.67	24.52	4.88	24.25	6.07	23.94	7.26	23.54	8.42	23.10	9.57	22.66	14.72	25
26	25.97	1.28	25.87	2.55	25.72	3.81	25.50	5.07	25.22	6.32	24.88	7.55	24.48	8.76	24.02	9.95	23.70	15.94	26
27	26.97	1.33	26.87	2.65	26.71	3.96	26.48	5.27	26.19	6.56	25.84	7.84	25.42	9.10	24.95	10.33	24.79	17.20	27
28	27.97	1.37	27.87	2.74	27.70	4.11	27.46	5.46	27.16	6.80	26.79	8.13	26.36	9.43	25.87	10.72	25.49	18.50	28
29	28.97	1.42	28.86	2.84	28.69	4.25	28.44	5.66	28.13	7.05	27.75	8.42	27.30	9.77	26.79	11.10	26.31	19.84	29
30	29.96	1.47	29.85	2.94	29.67	4.40	29.42	5.85	29.10	7.29	28.71	8.71	28.25	10.11	27.72	11.48	27.24	21.22	30
31	30.96	1.52	30.85	3.04	30.66	4.55	30.41	6.05	30.07	7.53	29.66	9.00	29.19	10.44	28.64	11.86	28.16	22.64	31
32	31.96	1.57	31.84	3.14	31.65	4.70	31.39	6.24	31.04	7.77	30.61	9.29	30.13	10.78	29.56	12.23	29.07	24.10	32
33	32.96	1.62	32.84	3.23	32.64	4.84	32.37	6.44	32.01	8.02	31.58	9.58	31.07	11.12	30.49	12.60	30.00	25.60	33
34	33.96	1.67	33.84	3.33	33.63	4.99	33.35	6.63	32.98	8.26	32.54	9.87	32.01	11.45	31.41	13.01	30.91	27.14	34
35	34.96	1.72	34.83	3.43	34.62	5.14	34.33	6.83	33.95	8.50	33.49	10.16	32.95	11.79	32.34	13.35	31.83	28.72	35
36	35.96	1.77	35.83	3.53	35.61	5.28	35.31	7.02	34.92	8.75	34.45	10.45	33.90	12.13	33.26	13.73	32.75	30.34	36
37	36.96	1.82	36.82	3.63	36.60	5.43	36.29	7.22	35.89	8.99	35.41	10.74	34.84	12.46	34.18	14.11	33.67	31.99	37
38	37.95	1.87	37.82	3.72	37.59	5.58	37.27	7.41	36.86	9.23	36.36	11.03	35.78	12.80	35.11	14.54	34.59	33.70	38
39	38.95	1.91	38.81	3.82	38.58	5.72	38.25	7.61	37.83	9.48	37.32	11.32	36.72	13.14	36.03	14.92	35.59	35.46	39
40	39.95	1.96	39.81	3.92	39.57	5.87	39.23	7.80	38.80	9.72	38.28	11.61	37.66	13.48	36.96	15.33	36.49	37.28	40
41	40.95	2.01	40.80	4.02	40.56	6.02	40.21	8.00	39.77	9.96	39.23	11.90	38.60	13.81	37.88	15.79	37.41	39.16	41
42	41.95	2.06	41.80	4.12	41.54	6.16	41.19	8.19	40.74	10.20	40.19	12.19	39.54	14.15	38.80	16.20	38.34	41.10	42
43	42.95	2.11	42.79	4.21	42.53	6.31	42.17	8.38	41.71	10.45	41.16	12.48	40.49	14.49	39.73	16.64	39.27	43.10	43
44	43.95	2.16	43.79	4.31	43.52	6.46	43.16	8.58	42.68	10.69	42.11	12.77	41.43	14.83	40.65	17.10	40.34	44.14	44
45	44.95	2.21	44.78	4.41	44.51	6.60	44.14	8.78	43.65	10.93	43.06	13.06	42.37	15.19	41.57	17.59	41.41	45.22	45
46	45.95	2.26	45.78	4.51	45.50	6.75	45.12	8.97	44.62	11.18	44.02	13.35	43.31	15.50	42.50	18.10	42.48	46.34	46
47	46.94	2.31	46.77	4.61	46.49	6.90	46.10	9.17	45.59	11.42	44.98	13.64	44.25	15.83	43.42	18.63	43.55	47.50	47
48	47.94	2.35	47.77	4.70	47.48	7.04	47.08	9.37	46.56	11.66	45.93	13.93	45.19	16.17	44.35	19.17	44.69	48.69	48
49	48.94	2.40	48.76	4.80	48.47	7.19	48.06	9.56	47.53	11.91	46.89	14.22	46.14	16.51	45.27	19.73	45.86	49.91	49
50	49.94	2.45	49.76	4.90	49.46	7.34	49.04	9.79	48.50	12.15	47.85	14.51	47.08	16.84	46.19	20.30	46.99	51.16	50
51	50.94	2.50	50.75	5.00	50.45	7.48	50.02	9.95	49.47	12.39	48.80	14.80	48.02	17.18	47.13	20.90	48.11	52.44	51
52	51.94	2.55	51.75	5.10	51.44	7.63	51.00	10.15	50.44	12.63	49.76	15.09	48.96	17.52	48.04	21.50	49.22	53.76	52

TRAVERSE TABLE, 66.

83

Distance	0 Point						1 Point						2 Points						Distance
	$\frac{1}{4}$		$\frac{1}{2}$		$\frac{3}{4}$		0		$\frac{1}{4}$		$\frac{1}{2}$		$\frac{3}{4}$		0				
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.			
61	60.93	2.99	60.71	5.98	60.34	8.95	59.83	11.90	59.17	14.82	58.37	17.71	57.43	20.55	56.36	23.34	61		
62	61.93	3.04	61.70	6.08	61.33	9.10	60.81	12.09	60.14	15.06	59.33	18.00	58.38	20.89	57.28	23.73	62		
63	62.92	3.09	62.70	6.17	62.32	9.24	61.79	12.29	61.11	15.31	60.29	18.29	59.33	21.22	58.21	24.11	63		
64	63.92	3.14	63.69	6.27	63.31	9.39	62.77	12.48	62.08	15.55	61.24	18.58	60.26	21.56	59.13	24.49	64		
65	64.92	3.19	64.69	6.37	64.30	9.54	63.75	12.68	63.05	15.79	62.20	18.87	61.20	21.90	60.05	24.87	65		
66	65.92	3.24	65.68	6.47	65.28	9.68	64.73	12.88	64.02	16.04	63.16	19.16	62.14	22.23	60.98	25.26	66		
67	66.92	3.29	66.68	6.57	66.27	9.83	65.71	13.07	64.99	16.28	64.11	19.45	63.08	22.57	61.90	25.64	67		
68	67.92	3.34	67.67	6.66	67.26	9.98	66.69	13.27	65.96	16.52	65.07	19.74	64.02	22.91	62.82	26.02	68		
69	68.92	3.39	68.67	6.76	68.25	10.12	67.67	13.46	66.93	16.77	66.03	20.03	64.97	23.24	63.75	26.40	69		
70	69.92	3.44	69.66	6.86	69.24	10.27	68.66	13.66	67.90	17.03	66.99	20.32	65.91	23.58	64.67	26.79	70		
71	70.92	3.48	70.66	6.96	70.23	10.42	69.64	13.85	68.87	17.25	67.94	20.61	66.85	23.92	65.60	27.17	71		
72	71.91	3.53	71.65	7.06	71.22	10.56	70.62	14.05	69.84	17.49	68.90	20.90	67.79	24.26	66.52	27.55	72		
73	72.91	3.58	72.65	7.15	72.21	10.71	71.60	14.24	70.81	17.74	69.86	21.19	68.73	24.59	67.44	27.94	73		
74	73.91	3.63	73.64	7.25	73.20	10.86	72.58	14.44	71.78	17.98	70.81	21.48	69.67	24.93	68.37	28.32	74		
75	74.91	3.68	74.64	7.35	74.19	11.00	73.56	14.63	72.75	18.22	71.77	21.77	70.62	25.27	69.29	28.70	75		
76	75.91	3.73	75.63	7.45	75.18	11.15	74.54	14.83	73.72	18.47	72.73	22.06	71.56	25.60	70.21	29.08	76		
77	76.91	3.78	76.63	7.55	76.17	11.30	75.52	15.02	74.69	18.71	73.68	22.35	72.50	25.94	71.14	29.47	77		
78	77.91	3.83	77.62	7.64	77.15	11.45	76.50	15.22	75.66	18.95	74.64	22.64	73.44	26.28	72.06	29.85	78		
79	78.91	3.88	78.62	7.74	78.14	11.59	77.48	15.41	76.63	19.20	75.60	22.93	74.38	26.61	72.99	30.23	79		
80	79.90	3.93	79.61	7.84	79.13	11.74	78.46	15.61	77.60	19.44	76.55	23.22	75.32	26.95	73.91	30.61	80		
81	80.90	3.98	80.61	7.94	80.12	11.88	79.44	15.80	78.57	19.68	77.51	23.51	76.27	27.29	74.83	31.00	81		
82	81.90	4.02	81.60	8.04	81.11	12.03	80.43	16.00	79.54	19.92	78.47	23.80	77.21	27.62	75.76	31.38	82		
83	82.90	4.07	82.60	8.14	82.10	12.18	81.41	16.19	80.51	20.17	79.43	24.09	78.15	27.96	76.68	31.76	83		
84	83.90	4.12	83.59	8.23	83.09	12.32	82.39	16.39	81.48	20.41	80.38	24.38	79.09	28.30	77.61	32.14	84		
85	84.90	4.17	84.59	8.33	84.08	12.47	83.37	16.58	82.45	20.65	81.34	24.67	80.03	28.63	78.53	32.53	85		
86	85.90	4.22	85.58	8.43	85.07	12.62	84.35	16.78	83.42	20.90	82.30	24.96	80.97	28.97	79.45	32.91	86		
87	86.90	4.27	86.58	8.53	86.06	12.76	85.33	16.97	84.39	21.14	83.25	25.21	81.91	29.31	80.38	33.29	87		
88	87.90	4.32	87.58	8.63	87.05	12.91	86.31	17.17	85.36	21.38	84.21	25.54	82.86	29.65	81.30	33.67	88		
89	88.90	4.37	88.57	8.72	88.04	13.06	87.29	17.36	86.33	21.62	85.17	25.83	83.80	29.98	82.23	34.06	89		
90	89.89	4.42	89.57	8.82	89.02	13.21	88.27	17.56	87.30	21.87	86.12	26.12	84.74	30.32	83.15	34.44	90		
91	90.89	4.47	90.56	8.92	90.01	13.35	89.25	17.75	88.27	22.11	87.08	26.41	85.68	30.66	84.07	34.82	91		
92	91.89	4.52	91.56	9.02	91.00	13.50	90.23	17.95	89.24	22.35	88.04	26.70	86.62	30.99	85.00	35.21	92		
93	92.89	4.56	92.55	9.12	91.99	13.65	91.21	18.14	90.21	22.60	89.00	27.00	87.56	31.33	85.92	35.59	93		
94	93.89	4.61	93.55	9.21	92.98	13.79	92.19	18.34	91.18	22.84	89.95	27.29	88.51	31.67	86.85	35.97	94		
95	94.89	4.66	94.54	9.31	93.97	13.94	93.18	18.54	92.15	23.08	90.91	27.58	89.45	32.00	87.77	36.35	95		
96	95.88	4.71	95.54	9.41	94.96	14.09	94.16	18.73	93.12	23.33	91.87	27.87	90.39	32.34	88.69	36.74	96		
97	96.88	4.76	96.53	9.51	95.95	14.23	95.14	18.92	94.09	23.57	92.82	28.16	91.33	32.68	89.62	37.11	97		
98	97.88	4.81	97.53	9.61	96.94	14.38	96.12	19.12	95.06	23.81	93.78	28.45	92.27	33.01	90.54	37.50	98		
99	98.88	4.86	98.52	9.70	97.93	14.53	97.10	19.31	96.03	24.05	94.74	28.74	93.21	33.35	91.46	37.88	99		
100	99.88	4.91	99.52	9.80	98.92	14.67	98.08	19.51	97.00	24.30	95.69	29.03	94.15	33.69	92.39	38.27	100		
101	100.9	4.96	100.5	9.90	99.91	14.82	99.06	19.70	97.97	24.54	96.65	29.32	95.10	34.03	93.31	38.65	101		
102	101.9	5.01	101.5	10.00	100.9	14.97	100.0	19.90	98.94	24.78	97.61	29.61	96.04	34.36	94.24	39.03	102		
103	102.9	5.05	102.5	10.10	101.9	15.11	101.0	20.09	99.91	25.03	98.56	29.90	96.98	34.70	95.16	39.42	103		
104	103.9	5.10	103.5	10.19	102.9	15.26	102.0	20.29	100.9	25.27	99.52	30.19	97.92	35.04	96.08	39.80	104		
105	104.9	5.15	104.5	10.29	103.9	15.41	103.0	20.48	101.9	25.51	100.5	30.48	98.86	35.37	97.01	40.18	105		
106	105.9	5.20	105.5	10.39	104.9	15.55	104.0	20.68	102.8	25.76	101.4	30.77	99.80	35.71	97.93	40.56	106		
107	106.9	5.25	106.5	10.49	105.8	15.70	104.9	20.88	103.8	26.00	102.4	31.06	100.7	36.05	98.86	40.95	107		
108	107.9	5.30	107.5	10.59	106.8	15.85	105.9	21.07	104.8	26.24	103.4	31.35	101.7	36.38	99.78	41.33	108		
109	108.9	5.35	108.5	10.68	107.8	15.99	106.9	21.27	105.7	26.48	104.3	31.64	102.6	36.72	100.7	41.71	109		
110	109.9	5.40	109.5	10.78	108.8	16.14	107.9	21.46	106.7	26.73	105.3	31.93	103.6	37.06	101.6	42.09	110		
111	110.9	5.45	110.5	10.88	109.8	16.29	108.9	21.66	107.7	26.97	106.2	32.22	104.5	37.39	102.6	42.48	111		
112	111.9	5.50	111.5	10.98	110.8	16.43	109.8	21.85	108.6	27.21	107.2	32.51	105.5	37.73	103.5	42.86	112		
113	112.9	5.55	112.5	11.08	111.8	16.58	110.8	22.05	109.6	27.46	108.1	32.80	106.4	38.07	104.4	43.24	113		
114	113.9	5.59	113.5	11.17	112.8	16.73	111.8	22.24	110.6	27.70	109.1	33.09	107.3	38.41	105.3	43.63	114		
115	114.9	5.64	114.4	11.27	113.8	16.87	112.8	22.44	111.6	27.94	110.0	33.38	108.3	38.74	106.2	44.01	115		
116	115.9	5.69	115.4	11.37	114.7	17.02	113.8	22.63	112.5	28.18	111.0	33.67	109.2	39.08	107.2	44.39	116		
117	116.9	5.74	116.4	11.47	115.7	17.17	114.8	22.83	113.5	28.43	112.0	33.96	110.2	39.42	108.1	44.77	117		
118	117.9	5.79																	

Distance	2 Points						3 Points												4 Points		Distance
	$\frac{1}{4}$		$\frac{1}{2}$		$\frac{3}{4}$		0		$\frac{1}{4}$		$\frac{1}{2}$		$\frac{3}{4}$		0						
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.					
1	0.90	0.43	0.88	0.47	0.86	0.51	0.83	0.56	0.80	0.60	0.77	0.63	0.74	0.67	0.71	0.71	1				
2	1.81	0.85	1.76	0.94	1.71	1.03	1.66	1.11	1.61	1.19	1.55	1.27	1.48	1.34	1.41	1.41	2				
3	2.71	1.28	2.65	1.41	2.57	1.54	2.49	1.67	2.41	1.79	2.32	1.90	2.22	2.01	2.12	2.12	3				
4	3.62	1.71	3.53	1.89	3.43	2.06	3.33	2.22	3.21	2.38	3.09	2.54	2.96	2.69	2.83	2.83	4				
5	4.52	2.14	4.41	2.36	4.29	2.57	4.16	2.78	4.02	2.98	3.86	3.17	3.70	3.36	3.53	3.53	5				
6	5.42	2.56	5.29	2.83	5.15	3.08	4.99	3.33	4.82	3.57	4.64	3.81	4.45	4.03	4.24	4.24	6				
7	6.33	2.99	6.17	3.30	6.00	3.60	5.82	3.89	5.62	4.17	5.41	4.44	5.19	4.70	4.95	4.95	7				
8	7.23	3.42	7.05	3.77	6.86	4.11	6.65	4.44	6.43	4.77	6.18	5.07	5.93	5.37	5.66	5.66	8				
9	8.14	3.85	7.94	4.24	7.72	4.63	7.48	5.00	7.23	5.36	6.96	5.71	6.67	6.04	6.36	6.36	9				
10	9.04	4.28	8.82	4.71	8.58	5.14	8.32	5.56	8.03	5.96	7.73	6.34	7.41	6.72	7.07	7.07	10				
11	9.94	4.70	9.70	5.18	9.43	5.65	9.15	6.11	8.83	6.55	8.50	6.98	8.15	7.39	7.78	7.78	11				
12	10.85	5.13	10.58	5.66	10.29	6.17	9.98	6.67	9.64	7.15	9.28	7.61	8.89	8.06	8.49	8.49	12				
13	11.75	5.56	11.46	6.13	11.15	6.68	10.81	7.22	10.44	7.74	10.05	8.25	9.63	8.73	9.19	9.19	13				
14	12.66	5.99	12.35	6.60	12.01	7.20	11.64	7.78	11.24	8.33	10.82	8.88	10.37	9.40	9.90	9.90	14				
15	13.56	6.41	13.23	7.07	12.87	7.71	12.47	8.33	12.05	8.93	11.59	9.51	11.11	10.07	10.61	10.61	15				
16	14.46	6.84	14.11	7.54	13.73	8.2	13.30	8.89	12.85	9.52	12.37	10.15	11.85	10.75	11.31	11.31	16				
17	15.37	7.27	14.99	8.01	14.58	8.74	14.13	9.45	13.65	10.12	13.14	10.78	12.60	11.42	12.02	12.02	17				
18	16.27	7.70	15.87	8.48	15.44	9.25	14.96	10.00	14.46	10.71	13.91	11.42	13.34	12.09	12.73	12.73	18				
19	17.18	8.13	16.76	8.95	16.30	9.77	15.80	10.56	15.26	11.31	14.69	12.05	14.08	12.76	13.43	13.43	19				
20	18.08	8.55	17.64	9.43	17.15	10.28	16.63	11.12	16.06	11.91	15.46	12.69	14.82	13.43	14.14	14.14	20				
21	18.98	8.98	18.52	9.90	18.01	10.80	17.46	11.67	16.87	12.51	16.23	13.32	15.56	14.10	14.85	14.85	21				
22	19.89	9.41	19.40	10.37	18.87	11.31	18.29	12.22	17.67	13.11	17.01	13.95	16.30	14.77	15.56	15.56	22				
23	20.79	9.83	20.28	10.84	19.73	11.82	19.12	12.78	18.47	13.70	17.78	14.59	17.04	15.45	16.26	16.26	23				
24	21.69	10.2	21.17	11.31	20.59	12.34	19.95	13.34	19.28	14.30	18.55	15.22	17.78	16.12	16.97	16.97	24				
25	22.60	10.69	22.05	11.78	21.44	12.85	20.78	13.89	20.08	14.89	19.33	15.86	18.52	16.79	17.68	17.68	25				
26	23.50	11.12	22.93	12.25	22.30	13.37	21.61	14.45	20.88	15.49	20.10	16.49	19.26	17.46	18.58	18.58	26				
27	24.41	11.55	23.81	12.72	23.16	13.88	22.45	15.00	21.68	16.09	20.87	17.12	20.01	18.13	19.09	19.09	27				
28	25.31	11.97	24.69	13.20	24.02	14.39	23.28	15.56	22.49	16.68	21.64	17.76	20.75	18.81	19.80	19.80	28				
29	26.21	12.40	25.58	13.69	24.88	14.91	24.11	16.12	23.29	17.28	22.42	18.39	21.49	19.48	20.51	20.51	29				
30	27.12	12.83	26.46	14.14	25.73	15.42	24.94	16.67	24.10	17.87	23.19	19.03	22.23	20.15	21.2	21.2	30				
31	28.02	13.25	27.34	14.61	26.59	15.94	25.78	17.22	24.90	18.46	23.96	19.67	22.97	20.82	21.92	21.92	31				
32	28.93	13.68	28.23	15.09	27.45	16.45	26.61	17.78	25.70	19.06	24.74	20.30	23.71	21.49	22.63	22.63	32				
33	29.83	14.11	29.11	15.56	28.31	16.96	27.44	18.34	26.51	19.66	25.51	20.93	24.45	22.16	23.33	23.33	33				
34	30.73	14.54	29.99	16.03	29.16	17.48	28.27	18.80	27.31	20.25	26.28	21.57	25.19	22.83	24.04	24.04	34				
35	31.64	14.97	30.87	16.51	30.02	17.99	29.10	19.45	28.11	20.85	27.05	22.21	25.93	23.51	24.75	24.75	35				
36	32.54	15.39	31.76	16.98	30.88	18.51	29.93	20.00	28.91	21.45	27.83	22.84	26.67	24.18	25.46	25.46	36				
37	33.45	15.82	32.64	17.45	31.74	19.02	30.76	20.56	29.72	22.04	28.60	23.47	27.42	24.85	26.16	26.16	37				
38	34.35	16.25	33.52	17.92	32.60	19.53	31.59	21.12	30.52	22.64	29.37	24.10	28.16	25.52	26.87	26.87	38				
39	35.26	16.68	34.40	18.39	33.45	20.05	32.42	21.67	31.32	23.23	30.15	24.74	28.90	26.19	27.58	27.58	39				
40	36.16	17.10	35.28	18.86	34.31	20.56	33.26	22.22	32.13	23.83	30.92	25.38	29.64	26.86	28.28	28.28	40				
41	37.06	17.53	36.16	19.33	35.17	21.08	34.09	22.78	32.93	24.42	31.69	26.01	30.38	27.53	28.99	28.99	41				
42	37.97	17.96	37.01	19.80	36.03	21.59	34.92	23.34	33.73	25.02	32.47	26.64	31.12	28.21	29.70	29.70	42				
43	38.87	18.39	37.92	20.27	36.88	22.10	35.75	23.89	34.54	25.62	33.24	27.28	31.86	28.83	30.41	30.41	43				
44	39.77	18.81	38.80	20.74	37.74	22.62	36.58	24.45	35.34	26.21	34.01	27.91	32.60	29.55	31.11	31.11	44				
45	40.68	19.24	39.69	21.21	38.60	23.13	37.41	25.00	36.14	26.82	34.78	28.55	33.34	30.22	31.82	31.82	45				
46	41.58	19.67	40.57	21.68	39.46	23.65	38.24	25.56	36.95	27.41	35.56	29.18	34.08	30.89	32.53	32.53	46				
47	42.49	20.10	41.45	22.15	40.32	24.16	39.08	26.12	37.75	28.01	36.33	29.81	34.82	31.57	33.23	33.23	47				
48	43.39	20.53	42.33	22.62	41.17	24.68	39.91	26.67	38.55	28.61	37.10	30.45	35.57	32.24	33.94	33.94	48				
49	44.29	20.95	43.21	23.09	42.03	25.19	40.74	27.23	39.36	29.20	37.88	31.08	36.31	32.91	34.65	34.65	49				
50	45.20	21.38	44.10	23.57	42.89	25.70	41.57	27.78	40.16	29.79	38.65	31.72	37.05	33.58	35.35	35.35	50				
51	46.10	21.81	44.98	24.04	43.74	26.22	42.40	28.34	40.96	30.38	39.42	32.55	37.79	34.25	36.06	36.06	51				
52	47.01	22.23	45.86	24.51	44.60	26.73	43.23	28.89	41.77	30.98	40.20	32.99	38.53	34.92	36.77	36.77	52				
53	47.91	22.66	46.74	24.98	45.46	27.25	44.07	29.45	42.57	31.57	40.97	33.62	39.27	35.59	37.47	37.47	53				
54	48.81	23.09	47.62	25.45	46.32	27.76	44.90	30.00	43.37	32.17	41.74	34.26	40.01	36.27	38.18	38.18	54				
55	49.72	23.52	48.51	25.92	47.18	28.27	45.73	30.56	44.18	32.76	42.52	34.89	40.75	36.94	38.89	38.89	55				
56	50.62	23.95	49.39	26.40	48.03	28.79	46.56	31.12	44.98	33.36	43.29	35.52	41.49	37.61	39.60	39.60	56				
57	51.53	24.37	50.27	26.87	48.89	29.30	47.39	31.67	45.78	33.96	44.06	36.16	42.23	38.28	40.30						

Distance	2 Points						3 Points						4 Points						Distance
	$\frac{1}{4}$		$\frac{1}{2}$		$\frac{3}{4}$		0		$\frac{1}{4}$		$\frac{1}{2}$		$\frac{3}{4}$		0				
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.			
61	55.14	26.08	53.80	28.75	52.32	31.36	50.72	33.80	49.00	36.34	47.15	38.70	45.20	40.97	43.13	43.13	61		
62	55.05	26.51	54.68	29.22	53.18	31.87	51.55	34.45	49.80	36.93	47.93	39.33	45.94	41.64	43.84	43.84	62		
63	54.95	26.94	55.56	29.70	54.04	32.39	52.38	35.00	50.60	37.53	48.70	39.96	46.68	42.31	44.55	44.55	63		
64	54.85	27.36	56.44	30.17	54.90	32.90	53.21	35.56	51.40	38.13	49.47	40.60	47.42	42.98	45.25	45.25	64		
65	54.76	27.79	57.33	30.64	55.75	33.42	54.04	36.11	52.21	38.72	50.25	41.24	48.16	43.65	45.96	45.96	65		
66	54.66	28.22	58.21	31.11	56.61	33.93	54.87	36.67	53.01	39.31	51.02	41.87	48.90	44.33	46.67	46.67	66		
67	54.57	28.65	59.09	31.58	57.47	34.44	55.71	37.23	53.81	39.91	51.79	42.50	49.64	44.99	47.38	47.38	67		
68	54.47	29.07	59.97	32.05	58.33	34.96	56.54	37.78	54.62	40.51	52.56	43.13	50.38	45.67	48.08	48.08	68		
69	54.37	29.51	60.85	32.52	59.19	35.47	57.37	38.34	55.42	41.11	53.34	43.77	51.13	46.34	48.79	48.79	69		
70	54.28	29.93	61.73	33.00	60.04	35.99	58.20	38.89	56.22	41.70	54.11	44.41	51.87	47.01	49.50	49.50	70		
71	54.18	30.36	62.62	33.47	60.90	36.50	59.03	39.45	57.03	42.29	54.88	45.04	52.61	47.68	50.20	50.20	71		
72	54.08	30.78	63.50	33.94	61.76	37.01	59.87	40.00	57.83	42.89	55.66	45.67	53.35	48.35	50.91	50.91	72		
73	53.99	31.21	64.38	34.41	62.62	37.53	60.70	40.56	58.63	43.49	56.43	46.31	54.09	49.02	51.62	51.62	73		
74	53.89	31.64	65.26	34.88	63.47	38.04	61.53	41.11	59.44	44.08	57.20	46.94	54.83	49.70	52.33	52.33	74		
75	53.80	32.07	66.14	35.35	64.33	38.56	62.36	41.67	60.24	44.68	57.98	47.58	55.57	50.37	53.03	53.03	75		
76	53.70	32.50	67.03	35.82	65.19	39.07	63.19	42.22	61.04	45.27	58.75	48.21	56.31	51.04	53.74	53.74	76		
77	53.60	32.92	67.91	36.29	66.05	39.58	64.02	42.78	61.85	45.87	59.52	48.84	57.05	51.71	54.45	54.45	77		
78	53.51	33.35	68.79	36.76	66.91	40.10	64.85	43.34	62.65	46.47	60.29	49.48	57.79	52.38	55.15	55.15	78		
79	53.41	33.78	69.67	37.24	67.76	40.61	65.70	43.89	63.45	47.06	61.07	50.11	58.54	53.06	55.86	55.86	79		
80	53.32	34.20	70.55	37.71	68.62	41.13	66.52	44.45	64.26	47.66	61.84	50.75	59.28	53.72	56.57	56.57	80		
81	53.22	34.63	71.44	38.18	69.48	41.64	67.35	45.00	65.06	48.25	62.61	51.38	60.02	54.40	57.28	57.28	81		
82	53.12	35.06	72.32	38.65	70.33	42.16	68.18	45.56	65.86	48.85	63.39	52.02	60.76	55.07	57.98	57.98	82		
83	53.03	35.49	73.20	39.12	71.19	42.67	69.01	46.11	66.67	49.44	64.16	52.65	61.50	55.74	58.69	58.69	83		
84	52.93	35.92	74.08	39.59	72.05	43.18	69.84	46.67	67.47	50.04	64.93	53.29	62.24	56.41	59.40	59.40	84		
85	52.84	36.34	74.96	40.07	72.91	43.70	70.67	47.23	68.28	50.64	65.71	53.92	62.98	57.08	60.10	60.10	85		
86	52.74	36.77	75.85	40.54	73.77	44.21	71.50	47.78	69.08	51.24	66.48	54.55	63.72	57.76	60.81	60.81	86		
87	52.64	37.20	76.73	41.01	74.62	44.73	72.34	48.34	69.88	51.83	67.25	55.19	64.46	58.43	61.52	61.52	87		
88	52.55	37.63	77.61	41.48	75.48	45.24	73.17	48.89	70.68	52.42	68.02	55.82	65.20	59.10	62.22	62.22	88		
89	52.45	38.06	78.49	41.95	76.34	45.75	74.00	49.45	71.48	53.02	68.80	56.46	65.94	59.77	62.93	62.93	89		
90	52.36	38.49	79.37	42.42	77.20	46.27	74.83	50.00	72.29	53.61	69.57	57.09	66.69	60.44	63.64	63.64	90		
91	52.26	38.92	80.26	42.90	78.05	46.78	75.66	50.56	73.09	54.21	70.34	57.73	67.43	61.11	64.35	64.35	91		
92	52.16	39.35	81.14	43.37	78.91	47.30	76.49	51.11	73.90	54.80	71.12	58.36	68.17	61.78	65.05	65.05	92		
93	52.07	39.78	82.02	43.84	79.77	47.81	77.33	51.67	74.70	55.40	71.89	59.00	68.91	62.46	65.76	65.76	93		
94	51.97	40.20	82.90	44.31	80.63	48.32	78.16	52.22	75.50	56.00	72.66	59.61	69.65	63.13	66.47	66.47	94		
95	51.88	40.63	83.78	44.78	81.49	48.84	79.00	52.78	76.30	56.59	73.44	60.26	70.39	63.80	67.17	67.17	95		
96	51.78	41.06	84.67	45.25	82.34	49.35	79.83	53.34	77.12	57.19	74.21	60.90	71.13	64.47	67.88	67.88	96		
97	51.68	41.49	85.55	45.72	83.20	49.87	80.66	53.89	77.91	57.78	74.98	61.53	71.87	65.14	68.59	68.59	97		
98	51.59	41.91	86.43	46.19	84.06	50.38	81.49	54.45	78.71	58.38	75.75	62.17	72.61	65.82	69.30	69.30	98		
99	51.49	42.34	87.31	46.66	84.92	50.89	82.32	55.00	79.52	58.98	76.53	62.80	73.35	66.49	70.00	70.00	99		
100	51.40	42.76	88.19	47.14	85.77	51.41	83.15	55.56	80.32	59.57	77.30	63.44	74.00	67.16	70.71	70.71	100		
101	51.30	43.18	89.07	47.61	86.63	51.92	83.98	56.11	81.12	60.17	78.07	64.07	74.84	67.83	71.42	71.42	101		
102	51.20	43.61	89.96	48.08	87.49	52.44	84.81	56.67	81.93	60.76	78.85	64.71	75.58	68.50	72.12	72.12	102		
103	51.11	44.04	90.84	48.55	88.35	52.95	85.64	57.22	82.73	61.36	79.62	65.34	76.32	69.17	72.83	72.83	103		
104	51.01	44.47	91.72	49.02	89.21	53.47	86.47	57.78	83.53	61.95	80.39	65.97	77.06	69.84	73.54	73.54	104		
105	50.92	44.90	92.60	49.50	90.06	53.98	87.31	58.34	84.34	62.55	81.17	66.61	77.80	70.52	74.25	74.25	105		
106	50.82	45.33	93.48	49.96	90.92	54.49	88.14	58.89	85.14	63.15	81.94	67.24	78.54	71.19	74.95	74.95	106		
107	50.72	45.75	94.37	50.44	91.78	55.01	88.98	59.45	85.94	63.74	82.71	67.88	79.28	71.86	75.66	75.66	107		
108	50.63	46.18	95.25	50.91	92.64	55.52	89.80	60.00	86.75	64.34	83.48	68.51	80.02	72.53	76.37	76.37	108		
109	50.53	46.61	96.13	51.38	93.50	56.04	90.63	60.56	87.55	64.93	84.26	69.15	80.76	73.20	77.07	77.07	109		
110	50.44	47.03	97.01	51.85	94.35	56.55	91.46	61.11	88.35	65.53	85.03	69.78	81.50	73.87	77.78	77.78	110		
111	50.34	47.46	97.89	52.32	95.21	57.06	92.29	61.67	89.16	66.12	85.80	70.42	82.25	74.54	78.49	78.49	111		
112	50.24	47.89	98.78	52.79	96.07	57.58	93.12	62.22	89.96	66.72	86.58	71.00	82.99	75.22	79.20	79.20	112		
113	50.14	48.31	99.66	53.27	96.92	58.09	93.96	62.78	90.76	67.31	87.35	71.68	83.73	75.89	79.90	79.90	113		
114	50.04	48.74	100.55	53.74	97.78	58.61	94.79	63.34	91.57	67.91	88.12	72.32	84.47	76.56	80.61	80.61	114		
115	49.94	49.17	101.44	54.21	98.64	59.12	95.62	63.89	92.37	68.51	88.90	72.95	85.21	77.23	81.32	81.32	115		
116	49.84	49.60	102.33	54.68	99.50	59.63	96.45	64.45	93.17	69.10	89.67	73.58	85.95	77.90	82.02	82.02	116		
117	49.74	50.03	103.22	55.15	100.40	60.15	97.28												

Distance	0 Degree						1 Degree.								Distance
	15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1,00	0,00	1,00	0,01	1,00	0,01	1,00	0,02	1,00	0,02	1,00	0,03	1,00	0,03	1
2	2,00	0,01	2,00	0,02	2,00	0,03	2,00	0,04	2,00	0,04	2,00	0,05	2,00	0,06	2
3	3,00	0,01	3,00	0,03	3,00	0,04	3,00	0,05	3,00	0,07	3,00	0,08	3,00	0,09	3
4	4,00	0,02	4,00	0,03	4,00	0,05	4,00	0,07	4,00	0,09	4,00	0,10	4,00	0,12	4
5	5,00	0,02	5,00	0,04	5,00	0,07	5,00	0,09	5,00	0,11	5,00	0,13	5,00	0,15	5
6	6,00	0,03	6,00	0,05	6,00	0,08	6,00	0,11	6,00	0,13	6,00	0,16	6,00	0,18	6
7	7,00	0,03	7,00	0,06	7,00	0,09	7,00	0,12	7,00	0,15	7,00	0,18	7,00	0,21	7
8	8,00	0,04	8,00	0,07	8,00	0,10	8,00	0,14	8,00	0,18	8,00	0,21	8,00	0,25	8
9	9,00	0,04	9,00	0,08	9,00	0,12	9,00	0,16	9,00	0,20	9,00	0,24	9,00	0,28	9
10	10,00	0,04	10,00	0,09	10,00	0,13	10,00	0,18	10,00	0,22	10,00	0,26	10,00	0,31	10
11	11,00	0,05	11,00	0,10	11,00	0,14	11,00	0,19	11,00	0,24	11,00	0,28	11,00	0,34	11
12	12,00	0,05	12,00	0,10	12,00	0,16	12,00	0,21	12,00	0,26	12,00	0,31	11,99	0,37	12
13	13,00	0,06	13,00	0,11	13,00	0,17	13,00	0,23	13,00	0,28	13,00	0,34	12,99	0,40	13
14	14,00	0,06	14,00	0,12	14,00	0,18	14,00	0,25	14,00	0,31	14,00	0,37	13,99	0,43	14
15	15,00	0,07	15,00	0,13	15,00	0,20	15,00	0,26	15,00	0,33	15,00	0,39	14,99	0,46	15
16	16,00	0,07	16,00	0,14	16,00	0,21	16,00	0,28	16,00	0,35	16,00	0,42	15,99	0,49	16
17	17,00	0,07	17,00	0,15	17,00	0,22	17,00	0,30	17,00	0,37	17,00	0,45	16,99	0,52	17
18	18,00	0,08	18,00	0,16	18,00	0,24	18,00	0,32	18,00	0,39	17,99	0,47	17,99	0,55	18
19	19,00	0,08	19,00	0,17	19,00	0,25	19,00	0,33	19,00	0,42	18,99	0,50	18,99	0,58	19
20	20,00	0,09	20,00	0,17	20,00	0,26	20,00	0,35	20,00	0,44	19,99	0,52	19,99	0,61	20
21	21,00	0,09	21,00	0,18	21,00	0,28	21,00	0,37	21,00	0,46	20,99	0,55	20,99	0,64	21
22	22,00	0,10	22,00	0,19	22,00	0,29	22,00	0,38	22,00	0,48	21,99	0,58	21,99	0,67	22
23	23,00	0,10	23,00	0,20	23,00	0,30	23,00	0,40	23,00	0,50	22,99	0,60	22,99	0,70	23
24	24,00	0,11	24,00	0,21	24,00	0,31	24,00	0,42	24,00	0,52	23,99	0,63	23,99	0,73	24
25	25,00	0,11	25,00	0,22	25,00	0,33	25,00	0,44	24,99	0,55	24,99	0,65	24,99	0,76	25
26	26,00	0,11	26,00	0,23	26,00	0,34	26,00	0,45	25,99	0,57	25,99	0,68	25,99	0,79	26
27	27,00	0,12	27,00	0,24	27,00	0,35	27,00	0,47	26,99	0,59	26,99	0,71	26,99	0,83	27
28	28,00	0,12	28,00	0,24	28,00	0,37	28,00	0,49	27,99	0,61	27,99	0,73	27,99	0,86	28
29	29,00	0,13	29,00	0,25	29,00	0,38	29,00	0,51	28,99	0,63	28,99	0,76	28,99	0,89	29
30	30,00	0,13	30,00	0,26	30,00	0,39	30,00	0,52	29,99	0,65	29,99	0,79	29,99	0,92	30
31	31,00	0,14	31,00	0,27	31,00	0,41	31,00	0,54	30,99	0,68	30,99	0,81	30,99	0,95	31
32	32,00	0,14	32,00	0,28	32,00	0,42	32,00	0,56	31,99	0,70	31,99	0,84	31,99	0,98	32
33	33,00	0,14	33,00	0,29	33,00	0,43	33,00	0,58	32,99	0,72	32,99	0,86	32,99	1,01	33
34	34,00	0,15	34,00	0,30	34,00	0,44	33,99	0,59	33,99	0,74	33,99	0,89	33,99	1,04	34
35	35,00	0,15	35,00	0,31	35,00	0,46	34,99	0,61	34,99	0,76	34,99	0,92	34,99	1,07	35
36	36,00	0,16	36,00	0,31	36,00	0,47	35,99	0,63	35,99	0,79	35,99	0,94	35,99	1,10	36
37	37,00	0,16	37,00	0,32	37,00	0,48	36,99	0,65	36,99	0,81	36,99	0,97	36,98	1,13	37
38	38,00	0,17	38,00	0,33	38,00	0,50	37,99	0,66	37,99	0,83	37,99	0,99	37,98	1,16	38
39	39,00	0,17	39,00	0,34	39,00	0,51	38,99	0,68	38,99	0,85	38,99	1,02	38,98	1,19	39
40	40,00	0,17	40,00	0,35	40,00	0,52	39,99	0,70	39,99	0,87	39,99	1,05	39,98	1,22	40
41	41,00	0,18	41,00	0,36	41,00	0,54	40,99	0,72	40,99	0,89	40,99	1,07	40,98	1,25	41
42	42,00	0,18	42,00	0,37	42,00	0,55	41,99	0,73	41,99	0,92	41,99	1,10	41,98	1,28	42
43	43,00	0,19	43,00	0,38	43,00	0,56	42,99	0,75	42,99	0,94	42,99	1,13	42,98	1,31	43
44	44,00	0,19	44,00	0,38	44,00	0,58	43,99	0,77	43,99	0,96	43,99	1,15	43,98	1,34	44
45	45,00	0,20	45,00	0,39	45,00	0,59	44,99	0,79	44,99	0,98	44,99	1,18	44,98	1,37	45
46	46,00	0,20	46,00	0,40	46,00	0,60	45,99	0,80	45,99	1,00	45,99	1,20	45,98	1,40	46
47	47,00	0,21	47,00	0,41	47,00	0,61	46,99	0,82	46,99	1,03	46,99	1,23	46,98	1,44	47
48	48,00	0,21	48,00	0,42	48,00	0,63	47,99	0,84	47,99	1,05	47,98	1,26	47,98	1,47	48
49	49,00	0,21	49,00	0,43	49,00	0,64	48,99	0,86	48,99	1,07	48,98	1,28	48,98	1,50	49
50	50,00	0,22	50,00	0,44	50,00	0,65	49,99	0,87	49,99	1,09	49,98	1,31	49,98	1,53	50
51	51,00	0,22	51,00	0,45	50,99	0,67	50,99	0,89	50,99	1,11	50,98	1,34	50,98	1,56	51
52	52,00	0,23	52,00	0,45	51,99	0,68	51,99	0,91	51,99	1,14	51,98	1,36	51,98	1,59	52
53	53,00	0,23	53,00	0,46	52,99	0,69	52,99	0,93	52,99	1,16	52,98	1,39	52,98	1,62	53
54	54,00	0,24	54,00	0,47	53,99	0,71	53,99	0,94	53,99	1,18	53,98	1,41	53,98	1,65	54
55	55,00	0,24	55,00	0,48	54,99	0,72	54,99	0,96	54,99	1,20	54,98	1,44	54,98	1,68	55
56	56,00	0,24	56,00	0,49	55,99	0,73	55,99	0,98	55,99	1,22	55,98	1,47	55,98	1,71	56
57	57,00	0,25	57,00	0,50	56,99	0,75	56,99	1,00	56,99	1,24	56,98	1,49	56,97	1,74	57
58	58,00	0,25	58,00	0,51	57,99	0,76	57,99	1,01	57,99	1,27	57,98	1,52	57,97	1,77	58
59	59,00	0,26	59,00	0,51	58,99	0,77	58,99	1,03	58,99	1,29	58,98	1,54	58,97	1,80	59
60	60,00	0,26	60,00	0,52	59,99	0,79	59,99	1,05	59,99	1,31	59,98	1,57	59,97	1,83	60
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance
	45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.		
	89 Degrees 57, 88 Degrees 29,														

0 Degree ,00							1 Degree ,01								Distance																
15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.																			
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.																		
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.																		
61	61,00	0,27	61,00	0,53	60,99	0,80	60,99	1,06	60,98	1,33	60,98	1,60	60,97	1,86	61																
62	62,00	0,27	62,00	0,54	61,99	0,81	61,99	1,08	61,98	1,35	61,98	1,62	61,97	1,89	62																
63	63,00	0,28	63,00	0,55	62,99	0,82	62,99	1,10	62,98	1,38	62,98	1,65	62,97	1,92	63																
64	64,00	0,28	64,00	0,56	63,99	0,84	63,99	1,12	63,98	1,40	63,98	1,67	63,97	1,95	64																
65	65,00	0,28	65,00	0,57	64,99	0,85	64,99	1,13	64,98	1,42	64,98	1,70	64,97	1,99	65																
66	66,00	0,29	66,00	0,58	65,99	0,86	65,99	1,15	65,98	1,44	65,98	1,73	65,97	2,02	66																
67	67,00	0,29	67,00	0,58	66,99	0,88	66,99	1,17	66,98	1,46	66,98	1,75	66,97	2,05	67																
68	68,00	0,30	68,00	0,59	67,99	0,89	67,99	1,19	67,98	1,48	67,98	1,78	67,97	2,08	68																
69	69,00	0,30	69,00	0,60	68,99	0,90	68,99	1,20	68,98	1,51	68,98	1,81	68,97	2,11	69																
70	70,00	0,31	70,00	0,61	69,99	0,92	69,99	1,22	69,98	1,53	69,98	1,83	69,97	2,14	70																
71	71,00	0,31	71,00	0,62	70,99	0,93	70,99	1,24	70,98	1,55	70,98	1,86	70,97	2,17	71																
72	72,00	0,31	72,00	0,63	71,99	0,94	71,99	1,26	71,98	1,57	71,98	1,88	71,97	2,20	72																
73	73,00	0,32	73,00	0,64	72,99	0,96	72,99	1,27	72,98	1,59	72,98	1,91	72,97	2,23	73																
74	74,00	0,32	74,00	0,65	73,99	0,97	73,99	1,29	73,98	1,62	73,98	1,94	73,97	2,26	74																
75	75,00	0,33	75,00	0,65	74,99	0,98	74,99	1,31	74,98	1,64	74,98	1,96	74,97	2,29	75																
76	76,00	0,33	76,00	0,66	75,99	0,99	75,99	1,33	75,98	1,66	75,97	1,99	75,97	2,32	76																
77	77,00	0,34	77,00	0,67	76,99	1,01	76,99	1,34	76,98	1,68	76,97	2,02	76,97	2,35	77																
78	78,00	0,34	78,00	0,68	77,99	1,02	77,99	1,36	77,98	1,70	77,97	2,04	77,96	2,38	78																
79	79,00	0,35	79,00	0,69	78,99	1,03	78,99	1,38	78,98	1,72	78,97	2,07	78,96	2,41	79																
80	80,00	0,35	80,00	0,70	79,99	1,05	79,99	1,40	79,98	1,75	79,97	2,09	79,96	2,44	80																
81	81,00	0,35	81,00	0,71	80,99	1,06	80,99	1,41	80,98	1,77	80,97	2,12	80,96	2,47	81																
82	82,00	0,36	82,00	0,72	81,99	1,07	81,99	1,43	81,98	1,79	81,97	2,15	81,96	2,50	82																
83	83,00	0,36	83,00	0,72	82,99	1,09	82,99	1,45	82,98	1,81	82,97	2,17	82,96	2,54	83																
84	84,00	0,37	84,00	0,73	83,99	1,10	83,99	1,47	83,98	1,83	83,97	2,20	83,96	2,57	84																
85	85,00	0,37	85,00	0,74	84,99	1,11	84,99	1,48	84,98	1,85	84,97	2,23	84,96	2,60	85																
86	86,00	0,38	86,00	0,75	85,99	1,13	85,99	1,50	85,98	1,88	85,97	2,25	85,96	2,63	86																
87	87,00	0,38	87,00	0,76	86,99	1,14	86,99	1,52	86,98	1,90	86,97	2,28	86,96	2,66	87																
88	88,00	0,38	88,00	0,77	87,99	1,15	87,99	1,54	87,98	1,92	87,97	2,30	87,96	2,69	88																
89	89,00	0,39	89,00	0,78	88,99	1,16	88,99	1,55	88,98	1,94	88,97	2,33	88,96	2,72	89																
90	90,00	0,39	90,00	0,79	89,99	1,18	89,99	1,57	89,98	1,96	89,97	2,36	89,96	2,75	90																
91	91,00	0,40	91,00	0,79	90,99	1,19	90,99	1,59	90,98	1,99	90,97	2,38	90,96	2,78	91																
92	92,00	0,40	92,00	0,80	91,99	1,20	91,99	1,61	91,98	2,01	91,97	2,41	91,96	2,81	92																
93	93,00	0,41	93,00	0,81	92,99	1,22	92,99	1,62	92,98	2,03	92,97	2,43	92,96	2,84	93																
94	94,00	0,41	94,00	0,82	93,99	1,23	93,99	1,64	93,98	2,05	93,97	2,46	93,96	2,87	94																
95	95,00	0,41	95,00	0,83	94,99	1,24	94,99	1,66	94,98	2,07	94,97	2,49	94,96	2,90	95																
96	96,00	0,42	96,00	0,84	95,99	1,26	95,99	1,68	95,98	2,09	95,97	2,51	95,96	2,94	96																
97	97,00	0,42	97,00	0,85	96,99	1,27	96,99	1,69	96,98	2,12	96,97	2,54	96,96	2,96	97																
98	98,00	0,43	98,00	0,86	97,99	1,28	97,99	1,71	97,98	2,14	97,97	2,57	97,96	2,99	98																
99	99,00	0,43	99,00	0,86	98,99	1,30	98,99	1,73	98,98	2,16	98,97	2,59	98,96	3,02	99																
100	100,00	0,44	100,00	0,87	99,99	1,31	99,99	1,75	99,98	2,18	99,97	2,62	99,96	3,05	100																
101	101,00	0,44	101,00	0,88	101,00	1,32	101,00	1,76	101,00	2,20	101,00	2,64	101,00	3,09	101																
102	102,00	0,45	102,00	0,89	102,00	1,34	102,00	1,78	102,00	2,23	102,00	2,67	102,00	3,12	102																
103	103,00	0,45	103,00	0,90	103,00	1,35	103,00	1,80	103,00	2,25	103,00	2,70	103,00	3,15	103																
104	104,00	0,45	104,00	0,91	104,00	1,36	104,00	1,82	104,00	2,27	104,00	2,72	104,00	3,18	104																
105	105,00	0,46	105,00	0,92	105,00	1,37	105,00	1,83	105,00	2,29	105,00	2,75	105,00	3,21	105																
106	106,00	0,46	106,00	0,92	106,00	1,39	106,00	1,85	106,00	2,31	106,00	2,78	106,00	3,24	106																
107	107,00	0,47	107,00	0,93	107,00	1,40	107,00	1,87	107,00	2,33	107,00	2,80	107,00	3,27	107																
108	108,00	0,47	108,00	0,94	108,00	1,41	108,00	1,89	108,00	2,36	108,00	2,83	108,00	3,30	108																
109	109,00	0,48	109,00	0,95	109,00	1,43	109,00	1,90	109,00	2,38	109,00	2,85	109,00	3,33	109																
110	110,00	0,48	110,00	0,96	110,00	1,44	110,00	1,92	110,00	2,40	110,00	2,88	110,00	3,36	110																
111	111,00	0,48	111,00	0,97	111,00	1,45	111,00	1,94	111,00	2,42	111,00	2,91	111,00	3,39	111																
112	112,00	0,49	112,00	0,98	112,00	1,47	112,00	1,96	112,00	2,44	112,00	2,93	112,00	3,42	112																
113	113,00	0,49	113,00	0,99	113,00	1,48	113,00	1,97	113,00	2,47	113,00	2,96	113,00	3,45	113																
114	114,00	0,50	114,00	0,99	114,00	1,49	114,00	1,99	114,00	2,49	114,00	2,98	114,00	3,48	114																
115	115,00	0,50	115,00	1,00	115,00	1,51	115,00	2,01	115,00	2,51	115,00	3,01	115,00	3,51	115																
116	116,00	0,51	116,00	1,01	116,00	1,52	116,00	2,03	116,00	2,53	116,00	3,04	116,00	3,54	116																
117	117,00	0,51	117,00	1,02	117,00	1,53	117,00	2,04	117,00	2,55	117,00	3,06	117,00	3,57	117																
118	118,00	0,52	118,00	1,03	118,00	1,54	118,00	2,06	118,00	2,57	118,00	3,09	118,00	3,60	118																
119	119,00	0,52	119,00	1,04	119,00	1,56	119,00	2,08	119,00	2,60	119,00	3,12	119,00	3,63	119																
120	120,00	0,52	120,00	1,05	120,00	1,57	120,00	2,09	120,00	2,61	120,00	3,14	120,00	3,66	120																
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance																
	45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.																		
89 Degrees															57,	88 Degrees															29,

Distance	2 Degrees								03	3 Degrees								05	Distance
	0 Min.		15 Min.		30 Min.		45 Min.			0 Min.		15 Min.		30 Min.		45 Min.			
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
1	1,00	0,04	1,00	0,04	1,00	0,04	1,00	0,05	1,00	0,05	1,00	0,06	1,00	0,06	1,00	0,06	1,00	0,06	
2	2,00	0,07	2,00	0,08	2,00	0,09	2,00	0,10	2,00	0,11	2,00	0,11	2,00	0,12	2,00	0,12	2,00	0,13	
3	3,00	0,11	3,00	0,12	3,00	0,13	3,00	0,14	3,00	0,15	3,00	0,17	3,00	0,18	3,00	0,18	3,00	0,19	
4	4,00	0,14	4,00	0,16	4,00	0,18	4,00	0,19	4,00	0,21	4,00	0,23	4,00	0,24	4,00	0,24	4,00	0,26	
5	5,00	0,18	5,00	0,20	5,00	0,22	5,00	0,24	5,00	0,26	5,00	0,28	5,00	0,31	5,00	0,31	5,00	0,33	
6	6,00	0,21	6,00	0,24	6,00	0,26	6,00	0,29	6,00	0,31	6,00	0,34	6,00	0,37	6,00	0,37	6,00	0,39	
7	7,00	0,24	7,00	0,28	7,00	0,31	7,00	0,34	7,00	0,37	7,00	0,40	7,00	0,43	7,00	0,43	7,00	0,46	
8	7,99	0,28	7,99	0,31	7,99	0,35	7,99	0,38	7,99	0,42	7,99	0,45	7,99	0,49	7,99	0,49	7,99	0,52	
9	8,99	0,31	8,99	0,35	8,99	0,39	8,99	0,43	8,99	0,47	8,99	0,51	8,99	0,55	8,99	0,55	8,99	0,58	
10	9,99	0,35	9,99	0,39	9,99	0,44	9,99	0,48	9,99	0,52	9,99	0,57	9,99	0,61	9,99	0,61	9,99	0,64	
11	10,99	0,38	10,99	0,43	10,99	0,48	10,99	0,53	10,99	0,58	10,99	0,62	10,99	0,67	10,99	0,67	10,99	0,70	
12	11,99	0,42	11,99	0,47	11,99	0,52	11,99	0,58	11,99	0,63	11,99	0,68	11,99	0,73	11,99	0,73	11,99	0,76	
13	12,99	0,45	12,99	0,51	12,99	0,57	12,99	0,62	12,99	0,68	12,99	0,73	12,99	0,79	12,99	0,79	12,99	0,82	
14	13,99	0,49	13,99	0,55	13,99	0,61	13,99	0,67	13,99	0,73	13,99	0,79	13,99	0,86	13,99	0,86	13,99	0,89	
15	14,99	0,52	14,99	0,59	14,99	0,65	14,99	0,72	14,99	0,79	14,99	0,85	14,99	0,92	14,99	0,92	14,99	0,95	
16	15,99	0,56	15,99	0,63	15,99	0,70	15,99	0,77	15,99	0,84	15,99	0,91	15,99	0,98	15,99	0,98	15,99	1,01	
17	16,99	0,59	16,99	0,67	16,99	0,74	16,99	0,82	16,99	0,89	16,99	0,96	16,99	1,04	16,99	1,04	16,99	1,07	
18	17,99	0,63	17,99	0,71	17,99	0,79	17,99	0,86	17,99	0,94	17,99	1,02	17,99	1,10	17,99	1,10	17,99	1,13	
19	18,99	0,66	18,99	0,75	18,99	0,83	18,99	0,91	18,99	0,99	18,99	1,08	18,99	1,16	18,99	1,16	18,99	1,19	
20	19,99	0,70	19,99	0,79	19,99	0,87	19,99	0,96	19,99	1,05	19,99	1,13	19,99	1,22	19,99	1,22	19,99	1,25	
21	20,99	0,73	20,99	0,83	20,99	0,92	20,99	1,01	20,99	1,10	20,99	1,19	20,99	1,28	20,99	1,28	20,99	1,31	
22	21,99	0,77	21,99	0,86	21,99	0,96	21,99	1,06	21,99	1,15	21,99	1,25	21,99	1,34	21,99	1,34	21,99	1,37	
23	22,99	0,80	22,99	0,90	22,99	1,00	22,99	1,10	22,99	1,20	22,99	1,30	22,99	1,40	22,99	1,40	22,99	1,43	
24	23,99	0,84	23,99	0,94	23,99	1,05	23,99	1,15	23,99	1,26	23,99	1,36	23,99	1,47	23,99	1,47	23,99	1,50	
25	24,99	0,87	24,99	0,98	24,99	1,09	24,99	1,20	24,99	1,31	24,99	1,42	24,99	1,53	24,99	1,53	24,99	1,56	
26	25,99	0,91	25,99	1,02	25,99	1,13	25,99	1,25	25,99	1,36	25,99	1,47	25,99	1,59	25,99	1,59	25,99	1,62	
27	26,99	0,94	26,99	1,06	26,99	1,18	26,99	1,30	26,99	1,41	26,99	1,53	26,99	1,65	26,99	1,65	26,99	1,68	
28	27,99	0,98	27,99	1,10	27,99	1,22	27,99	1,34	27,99	1,47	27,99	1,59	27,99	1,71	27,99	1,71	27,99	1,74	
29	28,99	1,01	28,99	1,14	28,99	1,27	28,99	1,39	28,99	1,52	28,99	1,64	28,99	1,77	28,99	1,77	28,99	1,80	
30	29,99	1,05	29,99	1,18	29,99	1,31	29,99	1,44	29,99	1,57	29,99	1,70	29,99	1,83	29,99	1,83	29,99	1,86	
31	30,99	1,08	30,99	1,22	30,99	1,35	30,99	1,49	30,99	1,62	30,99	1,76	30,99	1,89	30,99	1,89	30,99	1,92	
32	31,99	1,12	31,99	1,26	31,99	1,40	31,99	1,54	31,99	1,68	31,99	1,81	31,99	1,95	31,99	1,95	31,99	1,98	
33	32,99	1,15	32,99	1,30	32,99	1,44	32,99	1,58	32,99	1,73	32,99	1,87	32,99	2,02	32,99	2,02	32,99	2,05	
34	33,99	1,19	33,99	1,34	33,99	1,48	33,99	1,63	33,99	1,78	33,99	1,93	33,99	2,08	33,99	2,08	33,99	2,11	
35	34,99	1,22	34,99	1,37	34,99	1,53	34,99	1,68	34,99	1,83	34,99	1,99	34,99	2,14	34,99	2,14	34,99	2,17	
36	35,99	1,26	35,99	1,41	35,99	1,57	35,99	1,73	35,99	1,88	35,99	2,04	35,99	2,20	35,99	2,20	35,99	2,23	
37	36,99	1,29	36,99	1,45	36,99	1,61	36,99	1,78	36,99	1,94	36,99	2,10	36,99	2,26	36,99	2,26	36,99	2,29	
38	37,99	1,33	37,99	1,49	37,99	1,66	37,99	1,82	37,99	1,99	37,99	2,16	37,99	2,32	37,99	2,32	37,99	2,35	
39	38,99	1,36	38,99	1,53	38,99	1,70	38,99	1,87	38,99	2,04	38,99	2,21	38,99	2,38	38,99	2,38	38,99	2,41	
40	39,99	1,40	39,99	1,57	39,99	1,75	39,99	1,92	39,99	2,09	39,99	2,27	39,99	2,44	39,99	2,44	39,99	2,47	
41	40,99	1,43	40,99	1,61	40,99	1,79	40,99	1,97	40,99	2,15	40,99	2,33	40,99	2,50	40,99	2,50	40,99	2,53	
42	41,99	1,47	41,99	1,65	41,99	1,83	41,99	2,02	41,99	2,20	41,99	2,38	41,99	2,56	41,99	2,56	41,99	2,59	
43	42,99	1,50	42,99	1,69	42,99	1,88	42,99	2,06	42,99	2,25	42,99	2,44	42,99	2,63	42,99	2,63	42,99	2,66	
44	43,99	1,54	43,99	1,73	43,99	1,92	43,99	2,11	43,99	2,30	43,99	2,50	43,99	2,69	43,99	2,69	43,99	2,72	
45	44,99	1,57	44,99	1,77	44,99	1,96	44,99	2,16	44,99	2,36	44,99	2,55	44,99	2,75	44,99	2,75	44,99	2,78	
46	45,99	1,61	45,99	1,81	45,99	2,01	45,99	2,21	45,99	2,41	45,99	2,61	45,99	2,81	45,99	2,81	45,99	2,84	
47	46,99	1,64	46,99	1,85	46,99	2,05	46,99	2,26	46,99	2,47	46,99	2,67	46,99	2,87	46,99	2,87	46,99	2,90	
48	47,99	1,68	47,99	1,88	47,99	2,09	47,99	2,30	47,99	2,51	47,99	2,72	47,99	2,93	47,99	2,93	47,99	2,96	
49	48,99	1,71	48,99	1,92	48,99	2,14	48,99	2,35	48,99	2,57	48,99	2,78	48,99	2,99	48,99	2,99	48,99	3,02	
50	49,99	1,75	49,99	1,96	49,99	2,18	49,99	2,40	49,99	2,62	49,99	2,84	49,99	3,05	49,99	3,05	49,99	3,08	
51	50,99	1,78	50,99	2,00	50,99	2,23	50,99	2,45	50,99	2,67	50,99	2,89	50,99	3,11	50,99	3,11	50,99	3,14	
52	51,99	1,82	51,99	2,04	51,99	2,27	51,99	2,50	51,99	2,72	51,99	2,95	51,99	3,18	51,99	3,18	51,99	3,21	
53	52,99	1,85	52,99	2,08	52,99	2,31	52,99	2,54	52,99	2,77	52,99	3,01	52,99	3,24	52,99	3,24	52,99	3,27	
54	53,99	1,89	53,99	2,12	53,99	2,36	53,99	2,59	53,99	2,83	53,99	3,06	53,99	3,30	53,99	3,30	53,99	3,33	
55	54,99	1,92	54,99	2,16	54,99	2,40	54,99	2,64	54,99	2,88	54,99	3,12	54,99	3,36	54,99	3,36	54,99	3,39	
56	55,99	1,95	55,99	2,20	55,99	2,44	55,99	2,69	55,99	2,93	55,99	3,18	55,99	3,42	55,99	3,42	55,99	3,45	
57	56,99	1,99	56,99	2,24	56,99	2,49	56,99	2,74	56,99	2,98	56,99	3,23	56,99	3,48	56,99	3,48	56,99	3,51	
58	57,99	2,02	57,99	2,28	57,99	2,53	57,99	2,78	57,99	3,04	57,99	3,29	57,99	3,54	57,99	3,54	57,99	3,57	
59	58,99	2,06	58,99	2,32	58,99	2,57	58,99	2,83	58,99	3,09	58,99	3,35	58,99	3,60	58,99	3,60	58,99	3,63	
60	59,99	2,09	59,99	2,36	59,99	2,62	59,99	2,88	59,99	3,14	59,99	3,40	59,99	3,66	59,99	3,66	59,99	3,69	
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.				
	88 Deg.								87 Degrees										
									19										

Distance	2 Degrees								3 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
61	60,96	2,13	60,95	2,40	60,94	2,66	60,93	2,93	60,92	3,19	60,90	3,46	60,89	3,72	60,87	3,99	61
62	61,96	2,16	61,95	2,43	61,94	2,70	61,93	2,98	61,92	3,25	61,90	3,51	61,88	3,79	61,87	4,06	62
63	62,96	2,20	62,95	2,47	62,94	2,75	62,93	3,02	62,92	3,30	62,90	3,57	62,88	3,85	62,87	4,12	63
64	63,96	2,23	63,95	2,51	63,94	2,79	63,93	3,07	63,91	3,35	63,90	3,63	63,88	3,91	63,86	4,19	64
65	64,96	2,27	64,95	2,55	64,94	2,84	64,93	3,12	64,91	3,40	64,90	3,69	64,88	3,97	64,86	4,25	65
66	65,96	2,30	65,95	2,59	65,94	2,88	65,92	3,17	65,91	3,46	65,89	3,74	65,88	4,03	65,86	4,32	66
67	66,96	2,34	66,95	2,63	66,94	2,92	66,92	3,22	66,91	3,51	66,89	3,80	66,88	4,09	66,86	4,38	67
68	67,96	2,37	67,95	2,67	67,94	2,97	67,92	3,26	67,91	3,56	67,89	3,86	67,87	4,16	67,86	4,45	68
69	68,96	2,41	68,95	2,71	68,94	3,01	68,92	3,31	68,91	3,61	68,89	3,91	68,87	4,22	68,85	4,51	69
70	69,96	2,44	69,95	2,75	69,93	3,05	69,92	3,36	69,91	3,66	69,89	3,97	69,87	4,28	69,85	4,58	70
71	70,96	2,48	70,95	2,79	70,93	3,10	70,92	3,41	70,90	3,72	70,89	4,03	70,87	4,34	70,85	4,64	71
72	71,96	2,51	71,95	2,83	71,93	3,14	71,92	3,46	71,90	3,77	71,88	4,08	71,87	4,40	71,85	4,71	72
73	72,96	2,55	72,94	2,87	72,93	3,18	72,92	3,50	72,90	3,82	72,88	4,14	72,86	4,46	72,84	4,77	73
74	73,96	2,58	73,94	2,91	73,93	3,23	73,92	3,55	73,90	3,87	73,88	4,20	73,86	4,52	73,84	4,84	74
75	74,96	2,61	74,94	2,94	74,93	3,27	74,92	3,60	74,90	3,93	74,88	4,25	74,86	4,58	74,84	4,91	75
76	75,96	2,65	75,94	2,98	75,93	3,31	75,92	3,65	75,90	3,98	75,88	4,31	75,86	4,64	75,84	4,97	76
77	76,96	2,69	76,94	3,02	76,93	3,36	76,92	3,70	76,90	4,03	76,88	4,37	76,86	4,70	76,84	5,04	77
78	77,96	2,73	77,94	3,06	77,93	3,40	77,92	3,74	77,89	4,08	77,87	4,42	77,85	4,76	77,83	5,10	78
79	78,96	2,76	78,94	3,10	78,93	3,45	78,92	3,79	78,89	4,14	78,87	4,48	78,85	4,82	78,83	5,17	79
80	79,96	2,79	79,94	3,14	79,93	3,49	79,92	3,84	79,89	4,19	79,87	4,54	79,85	4,88	79,83	5,23	80
81	80,96	2,83	80,94	3,18	80,92	3,53	80,91	3,89	80,89	4,24	80,87	4,59	80,85	4,95	80,83	5,30	81
82	81,96	2,86	81,94	3,22	81,92	3,58	81,91	3,94	81,89	4,29	81,87	4,65	81,85	5,01	81,83	5,36	82
83	82,96	2,90	82,94	3,26	82,92	3,62	82,91	3,99	82,89	4,34	82,87	4,71	82,84	5,07	82,82	5,44	83
84	83,96	2,93	83,94	3,30	83,92	3,66	83,91	4,03	83,89	4,40	83,87	4,76	83,84	5,13	83,82	5,49	84
85	84,96	2,97	84,94	3,34	84,92	3,71	84,90	4,08	84,88	4,45	84,86	4,82	84,84	5,19	84,82	5,56	85
86	85,96	3,00	85,94	3,38	85,92	3,75	85,90	4,13	85,88	4,50	85,86	4,88	85,84	5,25	85,82	5,62	86
87	86,96	3,04	86,94	3,42	86,92	3,79	86,90	4,18	86,88	4,55	86,86	4,93	86,84	5,31	86,82	5,69	87
88	87,96	3,07	87,94	3,46	87,92	3,84	87,90	4,22	87,88	4,61	87,86	4,99	87,84	5,37	87,82	5,76	88
89	88,96	3,11	88,94	3,49	88,92	3,88	88,90	4,27	88,88	4,66	88,86	5,05	88,84	5,43	88,82	5,82	89
90	89,96	3,14	89,94	3,53	89,92	3,93	89,90	4,32	89,88	4,71	89,86	5,10	89,84	5,50	89,82	5,89	90
91	90,96	3,18	90,94	3,57	90,92	3,97	90,90	4,37	90,88	4,76	90,86	5,17	90,84	5,56	90,82	5,95	91
92	91,96	3,21	91,94	3,61	91,92	4,01	91,90	4,41	91,87	4,82	91,85	5,22	91,83	5,62	91,80	6,02	92
93	92,96	3,25	92,94	3,65	92,92	4,05	92,90	4,46	92,87	4,87	92,85	5,27	92,83	5,68	92,80	6,08	93
94	93,96	3,28	93,94	3,69	93,92	4,10	93,90	4,51	93,87	4,92	93,85	5,33	93,83	5,74	93,80	6,15	94
95	94,96	3,32	94,94	3,73	94,92	4,14	94,90	4,56	94,87	4,97	94,85	5,39	94,82	5,80	94,80	6,21	95
96	95,96	3,35	95,94	3,77	95,92	4,19	95,90	4,61	95,87	5,03	95,85	5,44	95,82	5,86	95,79	6,28	96
97	96,96	3,39	96,94	3,81	96,92	4,23	96,90	4,65	96,87	5,08	96,84	5,50	96,82	5,92	96,79	6,34	97
98	97,96	3,42	97,94	3,85	97,92	4,28	97,90	4,70	97,87	5,13	97,84	5,55	97,82	5,98	97,79	6,41	98
99	98,96	3,46	98,94	3,89	98,92	4,32	98,90	4,75	98,87	5,18	98,84	5,61	98,82	6,04	98,79	6,48	99
100	99,96	3,49	99,94	3,93	99,92	4,36	99,90	4,80	99,86	5,23	99,84	5,67	99,81	6,11	99,79	6,54	100
101	100,96	3,53	100,94	3,97	100,92	4,41	100,90	4,85	100,87	5,29	100,84	5,73	100,81	6,17	100,79	6,61	101
102	101,96	3,56	101,94	4,01	101,92	4,45	101,90	4,89	101,87	5,34	101,84	5,78	101,81	6,23	101,79	6,67	102
103	102,96	3,60	102,94	4,04	102,92	4,49	102,90	4,94	102,87	5,39	102,84	5,84	102,81	6,29	102,79	6,74	103
104	103,96	3,63	103,94	4,08	103,92	4,54	103,90	4,99	103,87	5,44	103,84	5,90	103,81	6,35	103,79	6,80	104
105	104,96	3,67	104,94	4,12	104,92	4,58	104,90	5,04	104,87	5,50	104,84	5,95	104,81	6,41	104,79	6,87	105
106	105,96	3,70	105,94	4,16	105,92	4,62	105,90	5,09	105,87	5,55	105,84	6,01	105,81	6,47	105,79	6,93	106
107	106,96	3,73	106,94	4,20	106,92	4,67	106,90	5,13	106,87	5,60	106,84	6,07	106,81	6,53	106,79	7,00	107
108	107,96	3,77	107,94	4,24	107,92	4,71	107,90	5,18	107,87	5,65	107,84	6,12	107,81	6,59	107,79	7,06	108
109	108,96	3,80	108,94	4,28	108,92	4,76	108,90	5,23	108,87	5,71	108,84	6,18	108,81	6,66	108,79	7,13	109
110	109,96	3,84	109,94	4,32	109,92	4,80	109,90	5,28	109,87	5,76	109,84	6,24	109,81	6,72	109,79	7,19	110
111	110,96	3,87	110,94	4,36	110,92	4,84	110,90	5,33	110,87	5,81	110,84	6,29	110,81	6,78	110,79	7,26	111
112	111,96	3,91	111,94	4,40	111,92	4,89	111,90	5,37	111,87	5,86	111,84	6,35	111,81	6,84	111,79	7,33	112
113	112,96	3,94	112,94	4,44	112,92	4,93	112,90	5,42	112,87	5,92	112,84	6,41	112,81	6,90	112,79	7,39	113
114	113,96	3,98	113,94	4,48	113,92	4,97	113,90	5,47	113,87	5,97	113,84	6,48	113,81	6,96	113,79	7,46	114
115	114,96	4,01	114,94	4,51	114,92	5,02	114,90	5,52	114,87	6,02	114,84	6,52	114,81	7,02	114,79	7,52	115
116	115,96	4,05	115,94	4,55	115,92	5,06	115,90	5,57	115,87	6,07	115,84	6,58	115,81	7,08	115,79	7,59	116
117	116,96	4,08	116,94	4,59	116,92	5,10	116,90	5,62	116,87	6,12	116,84	6,63	116,81	7,14	116,79	7,65	117
118	117,96	4,12	117,94	4,63	117,92	5,15	117,90	5,66	117,87	6,18	117,84	6,69	117,81	7,20	117,79		

Distance	4 Degrees								07	5 Degrees								09	Distance
	0 Min.		15 Min.		30 Min.		45 Min.			0 Min.		15 Min.		30 Min.		45 Min.			
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
1	1,00	0,07	1,00	0,07	1,00	0,07	1,00	0,08	1,00	0,09	1,00	0,09	1,00	0,10	1,00	0,10	1,00	0,10	
2	2,00	0,14	2,00	0,15	1,99	0,16	1,99	0,17	1,99	0,17	1,99	0,18	1,99	0,19	1,99	0,20	1,99	0,20	
3	3,00	0,21	2,99	0,22	2,99	0,24	2,99	0,25	2,99	0,26	2,99	0,28	2,99	0,29	2,99	0,30	2,99	0,30	
4	4,00	0,28	3,99	0,30	3,99	0,31	3,99	0,33	3,99	0,35	3,98	0,37	3,98	0,38	3,98	0,40	3,98	0,40	
5	5,00	0,35	4,99	0,37	4,99	0,39	4,98	0,41	4,98	0,44	4,98	0,46	4,98	0,48	4,98	0,50	4,98	0,50	
6	6,00	0,42	5,98	0,45	5,98	0,47	5,98	0,49	5,98	0,52	5,98	0,55	5,97	0,58	5,97	0,60	5,97	0,60	
7	7,00	0,49	6,98	0,52	6,98	0,55	6,98	0,58	6,97	0,61	6,97	0,64	6,97	0,67	6,97	0,70	6,97	0,70	
8	8,00	0,56	7,98	0,59	7,98	0,63	7,97	0,66	7,97	0,70	7,97	0,73	7,96	0,76	7,96	0,80	7,96	0,80	
9	9,00	0,63	8,98	0,67	8,97	0,71	8,97	0,75	8,97	0,78	8,96	0,82	8,96	0,86	8,96	0,90	8,96	0,90	
10	9,98	0,70	9,97	0,74	9,97	0,79	9,97	0,83	9,96	0,87	9,96	0,92	9,95	0,96	9,95	1,00	9,95	1,00	
11	10,97	0,77	10,97	0,82	10,97	0,86	10,96	0,91	10,96	0,96	10,95	1,01	10,95	1,05	10,95	1,10	10,95	1,10	
12	11,97	0,84	11,97	0,89	11,96	0,94	11,96	0,99	11,95	1,05	11,95	1,10	11,95	1,15	11,94	1,20	11,94	1,20	
13	12,97	0,91	12,97	0,96	12,96	1,02	12,96	1,08	12,95	1,13	12,95	1,19	12,94	1,25	12,94	1,30	12,94	1,30	
14	13,97	0,98	13,96	1,04	13,96	1,10	13,95	1,16	13,95	1,22	13,94	1,28	13,94	1,34	13,93	1,40	13,93	1,40	
15	14,96	1,05	14,96	1,11	14,95	1,18	14,95	1,24	14,94	1,31	14,94	1,37	14,93	1,44	14,93	1,50	14,93	1,50	
16	15,96	1,12	15,96	1,19	15,95	1,26	15,95	1,33	15,94	1,40	15,93	1,46	15,93	1,53	15,92	1,60	15,92	1,60	
17	16,96	1,19	16,95	1,26	16,95	1,33	16,94	1,41	16,94	1,48	16,93	1,56	16,92	1,63	16,92	1,70	16,92	1,70	
18	17,96	1,26	17,95	1,33	17,94	1,41	17,94	1,49	17,93	1,57	17,92	1,66	17,92	1,73	17,91	1,80	17,91	1,80	
19	18,95	1,33	18,95	1,40	18,94	1,49	18,93	1,57	18,93	1,66	18,92	1,74	18,91	1,82	18,91	1,90	18,91	1,90	
20	19,95	1,40	19,95	1,48	19,94	1,57	19,93	1,66	19,92	1,74	19,91	1,83	19,91	1,92	19,90	2,00	19,90	2,00	
21	20,95	1,47	20,94	1,56	20,94	1,65	20,93	1,74	20,92	1,83	20,91	1,92	20,90	2,01	20,89	2,10	20,89	2,10	
22	21,95	1,54	21,94	1,63	21,93	1,73	21,93	1,82	21,92	1,92	21,91	2,01	21,90	2,11	21,89	2,20	21,89	2,20	
23	22,94	1,60	22,94	1,70	22,93	1,80	22,92	1,90	22,91	2,00	22,90	2,11	22,89	2,21	22,88	2,30	22,88	2,30	
24	23,94	1,67	23,93	1,78	23,93	1,88	23,92	1,99	23,91	2,09	23,90	2,20	23,89	2,30	23,88	2,40	23,88	2,40	
25	24,94	1,74	24,93	1,85	24,92	1,96	24,91	2,07	24,91	2,18	24,90	2,29	24,89	2,40	24,87	2,50	24,87	2,50	
26	25,94	1,81	25,93	1,93	25,92	2,04	25,91	2,15	25,90	2,27	25,89	2,38	25,88	2,49	25,87	2,60	25,87	2,60	
27	26,93	1,88	26,93	2,00	26,92	2,12	26,91	2,24	26,90	2,35	26,89	2,47	26,88	2,59	26,86	2,70	26,86	2,70	
28	27,93	1,95	27,92	2,08	27,91	2,20	27,90	2,32	27,89	2,44	27,88	2,56	27,87	2,68	27,86	2,80	27,86	2,80	
29	28,93	2,02	28,92	2,15	28,91	2,28	28,90	2,40	28,89	2,53	28,88	2,65	28,87	2,78	28,85	2,90	28,85	2,90	
30	29,93	2,09	29,92	2,22	29,91	2,35	29,90	2,48	29,89	2,62	29,87	2,75	29,86	2,88	29,83	3,00	29,83	3,00	
31	30,93	2,16	30,92	2,30	30,91	2,43	30,89	2,57	30,88	2,70	30,87	2,84	30,86	2,97	30,84	3,10	30,84	3,10	
32	31,92	2,23	31,91	2,37	31,90	2,51	31,89	2,65	31,88	2,79	31,87	2,93	31,85	3,07	31,84	3,20	31,84	3,20	
33	32,92	2,30	32,91	2,45	32,90	2,59	32,88	2,73	32,88	2,88	32,87	3,02	32,85	3,17	32,83	3,30	32,83	3,30	
34	33,92	2,37	33,91	2,52	33,90	2,66	33,88	2,82	33,87	2,96	33,86	3,11	33,85	3,26	33,83	3,40	33,83	3,40	
35	34,92	2,44	34,90	2,59	34,89	2,75	34,88	2,90	34,87	3,05	34,85	3,20	34,84	3,36	34,82	3,50	34,82	3,50	
36	35,91	2,51	35,90	2,67	35,89	2,83	35,88	2,98	35,86	3,14	35,85	3,29	35,84	3,45	35,82	3,60	35,82	3,60	
37	36,91	2,58	36,90	2,74	36,89	2,90	36,87	3,06	36,86	3,23	36,85	3,39	36,83	3,55	36,81	3,70	36,81	3,70	
38	37,91	2,65	37,90	2,82	37,88	2,98	37,87	3,15	37,86	3,31	37,84	3,48	37,83	3,64	37,81	3,80	37,81	3,80	
39	38,91	2,72	38,89	2,89	38,88	3,06	38,87	3,23	38,85	3,40	38,84	3,57	38,82	3,74	38,80	3,90	38,80	3,90	
40	39,90	2,79	39,89	2,96	39,88	3,14	39,86	3,31	39,85	3,49	39,83	3,66	39,82	3,83	39,80	4,00	39,80	4,00	
41	40,90	2,86	40,89	3,04	40,87	3,22	40,86	3,40	40,84	3,57	40,83	3,75	40,81	3,93	40,79	4,10	40,79	4,10	
42	41,90	2,93	41,89	3,11	41,87	3,30	41,86	3,48	41,84	3,66	41,82	3,84	41,81	4,03	41,79	4,20	41,79	4,20	
43	42,90	3,00	42,88	3,19	42,87	3,37	42,85	3,56	42,84	3,75	42,82	3,94	42,80	4,12	42,78	4,30	42,78	4,30	
44	43,89	3,07	43,88	3,26	43,87	3,45	43,85	3,64	43,83	3,84	43,82	4,03	43,80	4,22	43,78	4,40	43,78	4,40	
45	44,89	3,14	44,88	3,34	44,86	3,53	44,85	3,73	44,83	3,92	44,81	4,12	44,79	4,31	44,77	4,50	44,77	4,50	
46	45,89	3,21	45,87	3,41	45,86	3,61	45,84	3,81	45,83	4,00	45,81	4,21	45,79	4,41	45,77	4,60	45,77	4,60	
47	46,89	3,28	46,87	3,48	46,86	3,69	46,84	3,89	46,82	4,10	46,80	4,30	46,78	4,51	46,76	4,70	46,76	4,70	
48	47,88	3,35	47,87	3,56	47,85	3,77	47,84	3,97	47,82	4,18	47,80	4,39	47,78	4,60	47,76	4,80	47,76	4,80	
49	48,88	3,42	48,87	3,63	48,85	3,84	48,83	4,06	48,81	4,27	48,79	4,48	48,78	4,70	48,75	4,90	48,75	4,90	
50	49,88	3,49	49,86	3,71	49,85	3,92	49,83	4,14	49,81	4,36	49,79	4,58	49,77	4,79	49,75	5,00	49,75	5,00	
51	50,88	3,56	50,86	3,78	50,84	4,00	50,83	4,22	50,81	4,45	50,79	4,67	50,77	4,89	50,74	5,10	50,74	5,10	
52	51,87	3,63	51,86	3,85	51,84	4,08	51,82	4,31	51,80	4,55	51,78	4,76	51,76	4,99	51,73	5,20	51,73	5,20	
53	52,87	3,70	52,86	3,93	52,84	4,16	52,82	4,39	52,80	4,62	52,78	4,85	52,76	5,08	52,73	5,30	52,73	5,30	
54	53,87	3,77	53,85	4,00	53,83	4,24	53,82	4,47	53,80	4,71	53,77	4,94	53,75	5,18	53,73	5,40	53,73	5,40	
55	54,87	3,84	54,85	4,08	54,83	4,32	54,81	4,56	54,79	4,79	54,77	5,03	54,75	5,27	54,72	5,50	54,72	5,50	
56	55,86	3,91	55,85	4,15	55,83	4,39	55,81	4,64	55,79	4,88	55,77	5,12	55,74	5,37	55,72	5,70	55,72	5,70	
57	56,86	3,98	56,84	4,23	56,82	4,47	56,81	4,72	56,78	4,97	56,76	5,22	56,74	5,46	56,71	5,80	56,71	5,80	
58	57,86	4,05	57,84	4,30	57,82	4,55	57,80	4,80	57,78	5,06	57,76	5,31	57,73	5,56	57,71	5,90	57,71	5,90	
59	58,86	4,12	58,84	4,37	58,82	4,63	58,80	4,89	58,78	5,15	58,75	5,40	58,73	5,66	58,70	6,00	58,70	6,00	
60	59,8	4,19	59,84	4,45	59,82	4,71	59,79	4,97	59,77	5,22	59,75	5,49	59,72	5,75	59,70				
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance	Lat.	
	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.				
	36 Deg.																85 Degrees		
																	84 Degrees		
																		0,5	

4 Degrees																,07		5 Degrees																,09		Distance
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.						
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.					
60,85	4,26	60,83	4,52	60,81	4,79	60,79	5,05	60,77	5,32	60,74	5,58	60,72	5,85	60,69	6,11	60,67	6,38	60,64	6,64	60,61	6,90	60,58	7,16	60,55	7,42	60,52	7,68	60,49	7,94	60,46	8,20					
61,85	4,33	61,83	4,60	61,81	4,87	61,79	5,14	61,76	5,40	61,74	5,67	61,72	5,94	61,69	6,21	61,67	6,48	61,64	6,74	61,61	7,00	61,58	7,26	61,55	7,52	61,52	7,78	61,49	8,04	61,46	8,30					
62,85	4,40	62,83	4,67	62,81	4,94	62,78	5,22	62,76	5,49	62,74	5,77	62,71	6,04	62,68	6,31	62,67	6,58	62,64	6,84	62,61	7,10	62,58	7,36	62,55	7,62	62,52	7,88	62,49	8,14	62,46	8,40					
63,85	4,47	63,82	4,74	63,80	5,02	63,78	5,30	63,76	5,58	63,73	5,86	63,71	6,13	63,68	6,41	63,67	6,68	63,64	6,94	63,61	7,20	63,58	7,46	63,55	7,72	63,52	7,98	63,49	8,24	63,46	8,50					
64,85	4,54	64,82	4,81	64,80	5,10	64,78	5,38	64,75	5,67	64,73	5,95	64,70	6,23	64,67	6,51	64,67	6,78	64,64	7,04	64,61	7,30	64,58	7,56	64,55	7,82	64,52	8,08	64,49	8,34	64,46	8,60					
65,85	4,61	65,82	4,89	65,80	5,18	65,77	5,47	65,75	5,75	65,72	6,04	65,70	6,33	65,67	6,61	65,67	6,88	65,64	7,14	65,61	7,40	65,58	7,66	65,55	7,92	65,52	8,18	65,49	8,44	65,46	8,70					
66,85	4,67	66,82	4,97	66,79	5,26	66,77	5,55	66,74	5,84	66,72	6,13	66,69	6,42	66,66	6,71	66,66	6,98	66,63	7,24	66,61	7,47	66,58	7,73	66,55	7,99	66,52	8,25	66,49	8,51	66,46	8,77					
67,85	4,74	67,81	5,04	67,79	5,34	67,77	5,63	67,74	5,93	67,71	6,22	67,69	6,52	67,66	6,81	67,66	7,08	67,63	7,34	67,61	7,57	67,58	7,83	67,55	8,09	67,52	8,35	67,49	8,61	67,46	8,87					
68,85	4,81	68,81	5,11	68,79	5,41	68,76	5,71	68,74	6,02	68,71	6,31	68,68	6,61	68,65	6,91	68,65	7,18	68,63	7,44	68,61	7,67	68,58	7,93	68,55	8,19	68,52	8,45	68,49	8,71	68,46	8,97					
69,85	4,88	69,81	5,19	69,78	5,49	69,76	5,80	69,73	6,10	69,71	6,41	69,68	6,71	69,65	7,01	69,65	7,28	69,63	7,54	69,61	7,77	69,58	8,03	69,55	8,29	69,52	8,55	69,49	8,81	69,46	9,07					
70,85	4,95	70,81	5,26	70,78	5,57	70,76	5,88	70,73	6,19	70,70	6,50	70,67	6,81	70,64	7,11	70,64	7,38	70,63	7,64	70,61	7,87	70,58	8,13	70,55	8,39	70,52	8,65	70,49	8,91	70,46	9,17					
71,85	5,02	71,80	5,34	71,78	5,65	71,75	5,96	71,73	6,28	71,70	6,59	71,67	6,90	71,64	7,21	71,64	7,48	71,63	7,74	71,61	7,97	71,58	8,23	71,55	8,49	71,52	8,75	71,49	9,01	71,46	9,27					
72,85	5,09	72,80	5,41	72,78	5,73	72,75	6,04	72,72	6,36	72,69	6,68	72,66	7,00	72,63	7,31	72,63	7,58	72,63	7,84	72,61	8,07	72,58	8,33	72,55	8,59	72,52	8,85	72,49	9,11	72,46	9,37					
73,85	5,16	73,80	5,48	73,77	5,81	73,75	6,13	73,72	6,45	73,69	6,77	73,66	7,09	73,63	7,41	73,63	7,68	73,63	7,94	73,61	8,17	73,58	8,43	73,55	8,69	73,52	8,95	73,49	9,21	73,46	9,47					
74,85	5,23	74,79	5,56	74,77	5,88	74,74	6,21	74,71	6,54	74,69	6,86	74,66	7,19	74,63	7,51	74,63	7,78	74,63	8,04	74,61	8,27	74,58	8,53	74,55	8,79	74,52	9,05	74,49	9,31	74,46	9,57					
75,85	5,30	75,79	5,63	75,77	5,96	75,74	6,29	75,71	6,62	75,68	6,95	75,65	7,29	75,63	7,61	75,63	7,88	75,63	8,14	75,61	8,37	75,58	8,63	75,55	8,89	75,52	9,15	75,49	9,41	75,46	9,67					
76,85	5,37	76,79	5,71	76,76	6,04	76,74	6,38	76,71	6,71	76,68	7,05	76,65	7,39	76,63	7,71	76,63	7,98	76,63	8,24	76,61	8,47	76,58	8,73	76,55	8,99	76,52	9,25	76,49	9,51	76,46	9,77					
77,85	5,44	77,79	5,78	77,76	6,12	77,73	6,46	77,70	6,80	77,67	7,14	77,64	7,48	77,63	7,81	77,63	8,08	77,63	8,34	77,61	8,57	77,58	8,83	77,55	9,09	77,52	9,35	77,49	9,61	77,46	9,87					
78,85	5,51	78,78	5,86	78,76	6,20	78,73	6,54	78,70	6,89	78,67	7,23	78,64	7,57	78,63	7,91	78,63	8,18	78,63	8,44	78,61	8,67	78,58	8,93	78,55	9,19	78,52	9,45	78,49	9,71	78,46	9,97					
79,85	5,58	79,78	5,93	79,75	6,28	79,73	6,63	79,70	6,97	79,66	7,32	79,63	7,67	79,63	8,01	79,63	8,28	79,63	8,54	79,61	8,77	79,58	9,03	79,55	9,29	79,52	9,55	79,49	9,81	79,46	10,07					
80,85	5,65	80,78	6,00	80,75	6,36	80,72	6,71	80,69	7,06	80,66	7,41	80,63	7,76	80,63	8,11	80,63	8,38	80,63	8,64	80,61	8,87	80,58	9,13	80,55	9,39	80,52	9,65	80,49	9,91	80,46	10,17					
81,85	5,72	81,78	6,08	81,75	6,43	81,72	6,79	81,69	7,15	81,66	7,50	81,63	7,86	81,63	8,21	81,63	8,48	81,63	8,74	81,61	8,97	81,58	9,23	81,55	9,49	81,52	9,75	81,49	10,01	81,46	10,27					
82,85	5,79	82,77	6,15	82,75	6,51	82,72	6,87	82,68	7,24	82,65	7,60	82,62	7,96	82,63	8,31	82,63	8,58	82,63	8,84	82,61	9,07	82,58	9,33	82,55	9,59	82,52	9,85	82,49	10,11	82,46	10,37					
83,85	5,86	83,77	6,23	83,74	6,59	83,71	6,96	83,68	7,32	83,65	7,69	83,63	8,05	83,63	8,41	83,63	8,68	83,63	8,94	83,61	9,17	83,58	9,43	83,55	9,69	83,52	9,95	83,49	10,21	83,46	10,47					
84,85	5,93	84,77	6,30	84,74	6,67	84,71	7,04	84,68	7,41	84,64	7,78	84,63	8,15	84,63	8,51	84,63	8,78	84,63	9,04	84,61	9,27	84,58	9,53	84,55	9,79	84,52	10,05	84,49	10,31	84,46	10,57					
85,85	6,01	85,76	6,37	85,74	6,75	85,71	7,12	85,67	7,50	85,64	7,87	85,63	8,24	85,63	8,61	85,63	8,88	85,63	9,14	85,61	9,37	85,58	9,63	85,55	9,89	85,52	10,15	85,49	10,41	85,46	10,67					
86,85	6,07	86,76	6,45	86,73	6,83	86,70	7,21	86,67	7,58	86,63	7,96	86,63	8,33	86,63	8,71	86,63	9,08	86,63	9,34	86,61	9,57	86,58	9,83	86,55	10,09	86,52	10,35	86,49	10,61	86,46	10,87					
87,85	6,14	87,76	6,52	87,73	6,91	87,70	7,29	87,67	7,67	87,63	8,05	87,63	8,42	87,63	8,80	87,63	9,17	87,63	9,43	87,61	9,66	87,58	9,92	87,55	10,18	87,52	10,44	87,49	10,70	87,46	10,96					
88,85	6,21	88,76	6,60	88,73	6,98	88,70	7,37	88,66	7,76	88,63	8,14	88,59	8,53	88,55	8,91	88,55	9,28	88,55	9,54	88,53	9,77	88,50	10,03	88,47	10,29	88,44	10,55	88,41	10,81	88,38	11,07					
89,85	6,28	89,75	6,67	89,72	7,06	89,69	7,45	89,66	7,84	89,62	8,24	89,59	8,63	89,55	9,01	89,55	9,38	89,55	9,64	89,53	9,87	89,50	10,13	89,47	10,39	89,44	10,65	89,41	10,91	89,38	11,17					
90,85	6,35	90,75	6,74	90,72	7,14	90,69	7,54	90,65	7,93	90,62	8,33	90,58	8,72	90,54	9,11	90,54	9,48	90,54	9,74	90,53	9,97	90,50	10,23	90,47	10,49	90,44	10,75	90,41	11,01	90,38	11,27					
91,85	6,42	91,75	6,82	91,72	7,22	91,68	7,62	91,65	8,02	91,61	8,42	91,58	8,82	91,54	9,21	91,54	9,58	91,54	9,84	91,53	10,07	91,50	10,33	91,47	10,59	91,44	10,85	91,41	11,11	91,38	11,37					
92,85	6,49	92,75	6,89	92,71	7,30	92,68	7,70	92,65	8,11	92,61	8,51	92,57	8,92	92,53	9,31	92,53	9,68	92,53	9,94	92,53	10,1															

TRAVERSE TABLE, 67.

Distance	6 Degrees								7 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1.00	0.11	1.00	0.11	0.99	0.11	0.99	0.12	0.99	0.12	0.99	0.13	0.99	0.13	0.99	0.14	0.99
2	1.99	0.21	1.99	0.22	1.99	0.23	1.99	0.24	1.99	0.24	1.98	0.25	1.98	0.26	1.98	0.27	1.98
3	2.99	0.32	2.98	0.33	2.98	0.34	2.98	0.35	2.98	0.37	2.98	0.38	2.98	0.39	2.97	0.41	2.97
4	3.98	0.41	3.98	0.44	3.97	0.45	3.97	0.47	3.97	0.49	3.97	0.51	3.97	0.52	3.96	0.54	3.96
5	4.97	0.52	4.97	0.54	4.97	0.57	4.97	0.59	4.97	0.61	4.96	0.63	4.96	0.65	4.95	0.67	4.95
6	5.97	0.63	5.96	0.65	5.96	0.68	5.96	0.71	5.96	0.73	5.95	0.76	5.95	0.78	5.95	0.81	5.95
7	6.96	0.73	6.96	0.76	6.96	0.79	6.95	0.82	6.95	0.85	6.94	0.88	6.94	0.91	6.94	0.94	6.94
8	7.96	0.84	7.95	0.87	7.95	0.91	7.95	0.94	7.94	0.98	7.94	1.01	7.94	1.04	7.93	1.08	7.93
9	8.95	0.94	8.95	0.98	8.94	1.02	8.94	1.06	8.93	1.10	8.93	1.14	8.93	1.18	8.92	1.21	8.92
10	9.95	1.05	9.94	1.09	9.94	1.13	9.93	1.18	9.93	1.22	9.92	1.26	9.92	1.31	9.91	1.35	9.91
11	10.94	1.15	10.94	1.20	10.93	1.25	10.92	1.29	10.92	1.34	10.91	1.39	10.91	1.44	10.90	1.48	10.90
12	11.93	1.25	11.93	1.31	11.92	1.36	11.92	1.41	11.91	1.46	11.90	1.51	11.90	1.57	11.89	1.62	11.89
13	12.93	1.36	12.92	1.42	12.92	1.47	12.91	1.53	12.90	1.58	12.90	1.64	12.90	1.70	12.88	1.75	12.88
14	13.92	1.46	13.92	1.52	13.91	1.59	13.90	1.65	13.90	1.71	13.89	1.77	13.89	1.83	13.87	1.89	13.87
15	14.92	1.57	14.91	1.63	14.90	1.70	14.90	1.76	14.89	1.83	14.88	1.89	14.88	1.96	14.86	2.02	14.86
16	15.91	1.67	15.91	1.74	15.90	1.81	15.89	1.88	15.88	1.95	15.87	2.02	15.87	2.09	15.85	2.16	15.85
17	16.91	1.78	16.90	1.85	16.89	1.92	16.88	2.00	16.87	2.07	16.86	2.15	16.86	2.22	16.84	2.29	16.84
18	17.90	1.88	17.89	1.96	17.88	2.04	17.88	2.12	17.87	2.19	17.86	2.27	17.86	2.35	17.83	2.43	17.83
19	18.90	1.98	18.89	2.07	18.88	2.15	18.87	2.23	18.86	2.32	18.85	2.40	18.85	2.48	18.83	2.56	18.83
20	19.89	2.09	19.88	2.18	19.87	2.26	19.86	2.35	19.85	2.44	19.84	2.52	19.84	2.61	19.82	2.70	19.82
21	20.89	2.20	20.88	2.29	20.86	2.38	20.85	2.47	20.84	2.56	20.83	2.65	20.83	2.74	20.81	2.83	20.81
22	21.88	2.30	21.87	2.39	21.86	2.49	21.85	2.59	21.84	2.68	21.82	2.77	21.82	2.87	21.80	2.97	21.80
23	22.87	2.41	22.86	2.50	22.85	2.60	22.84	2.70	22.83	2.80	22.82	2.90	22.82	3.00	22.79	3.10	22.79
24	23.87	2.51	23.86	2.61	23.85	2.72	23.83	2.82	23.82	2.93	23.81	3.03	23.81	3.13	23.78	3.24	23.78
25	24.86	2.61	24.85	2.72	24.84	2.83	24.83	2.94	24.82	3.05	24.80	3.16	24.80	3.27	24.77	3.37	24.77
26	25.86	2.72	25.85	2.83	25.83	2.94	25.82	3.06	25.81	3.17	25.79	3.28	25.79	3.40	25.76	3.51	25.76
27	26.85	2.82	26.84	2.94	26.83	3.06	26.81	3.17	26.80	3.29	26.78	3.41	26.78	3.53	26.75	3.64	26.75
28	27.85	2.93	27.83	3.05	27.82	3.17	27.81	3.29	27.79	3.41	27.78	3.53	27.78	3.66	27.74	3.78	27.74
29	28.84	3.03	28.83	3.16	28.81	3.28	28.80	3.41	28.79	3.53	28.77	3.66	28.77	3.79	28.73	3.91	28.73
30	29.84	3.14	29.82	3.27	29.81	3.40	29.79	3.53	29.78	3.66	29.76	3.79	29.76	3.92	29.73	4.05	29.73
31	30.83	3.24	30.82	3.38	30.80	3.51	30.79	3.64	30.77	3.78	30.75	3.91	30.75	4.05	30.72	4.18	30.72
32	31.83	3.35	31.81	3.48	31.79	3.62	31.78	3.76	31.76	3.90	31.74	4.04	31.74	4.18	31.71	4.32	31.71
33	32.82	3.45	32.80	3.59	32.79	3.74	32.78	3.88	32.76	4.02	32.74	4.17	32.74	4.31	32.70	4.45	32.70
34	33.81	3.56	33.80	3.70	33.78	3.85	33.77	4.00	33.75	4.14	33.73	4.29	33.73	4.44	33.69	4.59	33.69
35	34.81	3.66	34.79	3.81	34.78	3.96	34.76	4.11	34.74	4.27	34.72	4.42	34.72	4.57	34.68	4.73	34.68
36	35.80	3.76	35.79	3.92	35.77	4.08	35.75	4.23	35.73	4.39	35.71	4.54	35.71	4.70	35.67	4.86	35.67
37	36.80	3.87	36.78	4.03	36.76	4.19	36.75	4.35	36.73	4.51	36.70	4.67	36.70	4.83	36.66	4.99	36.66
38	37.79	3.97	37.77	4.14	37.76	4.30	37.74	4.47	37.72	4.63	37.70	4.80	37.70	4.96	37.65	5.13	37.65
39	38.79	4.08	38.77	4.24	38.75	4.42	38.73	4.58	38.71	4.75	38.69	4.92	38.69	5.09	38.64	5.26	38.64
40	39.78	4.18	39.76	4.36	39.74	4.53	39.72	4.70	39.70	4.88	39.68	5.05	39.68	5.22	39.64	5.39	39.64
41	40.78	4.29	40.76	4.46	40.74	4.64	40.72	4.82	40.70	5.00	40.67	5.17	40.67	5.35	40.63	5.53	40.63
42	41.77	4.39	41.75	4.57	41.73	4.76	41.71	4.94	41.69	5.12	41.66	5.30	41.66	5.48	41.62	5.66	41.62
43	42.77	4.49	42.74	4.68	42.72	4.87	42.70	5.06	42.68	5.24	42.66	5.43	42.66	5.61	42.61	5.80	42.61
44	43.76	4.60	43.74	4.79	43.72	4.98	43.70	5.17	43.67	5.36	43.65	5.55	43.65	5.74	43.60	5.93	43.60
45	44.75	4.70	44.73	4.90	44.71	5.10	44.69	5.29	44.67	5.48	44.64	5.68	44.64	5.87	44.59	6.07	44.59
46	45.75	4.81	45.73	5.01	45.71	5.21	45.68	5.41	45.66	5.61	45.63	5.81	45.63	6.00	45.58	6.20	45.58
47	46.74	4.91	46.72	5.12	46.70	5.32	46.68	5.52	46.65	5.73	46.62	5.93	46.62	6.14	46.57	6.34	46.57
48	47.74	5.02	47.71	5.23	47.69	5.43	47.67	5.64	47.64	5.85	47.62	6.06	47.62	6.27	47.56	6.47	47.56
49	48.73	5.12	48.71	5.34	48.69	5.55	48.66	5.76	48.64	5.97	48.61	6.18	48.61	6.40	48.55	6.61	48.55
50	49.73	5.23	49.70	5.44	49.68	5.66	49.65	5.88	49.63	6.09	49.60	6.31	49.60	6.53	49.54	6.74	49.54
51	50.72	5.33	50.70	5.55	50.67	5.77	50.65	6.00	50.62	6.22	50.59	6.44	50.60	6.66	50.54	6.88	50.54
52	51.72	5.44	51.69	5.66	51.67	5.89	51.64	6.11	51.61	6.34	51.58	6.56	51.59	6.79	51.53	7.01	51.53
53	52.71	5.54	52.69	5.77	52.66	6.00	52.63	6.23	52.61	6.46	52.58	6.69	52.58	6.92	52.52	7.15	52.52
54	53.70	5.65	53.68	5.88	53.65	6.11	53.63	6.35	53.60	6.58	53.57	6.82	53.57	7.05	53.51	7.28	53.51
55	54.70	5.75	54.67	5.99	54.65	6.23	54.62	6.47	54.59	6.70	54.56	6.94	54.56	7.18	54.50	7.42	54.50
56	55.69	5.85	55.67	6.10	55.64	6.34	55.61	6.58	55.58	6.83	55.55	7.07	55.55	7.31	55.49	7.55	55.49
57	56.69	5.96	56.66	6.21	56.63	6.45	56.61	6.70	56.58	6.95	56.54	7.19	56.54	7.44	56.48	7.69	56.48
58	57.68	6.06	57.66	6.31	57.63	6.57	57.60	6.82	57.57	7.07	57.54	7.32	57.54	7.57	57.47	7.83	57.47
59	58.68	6.17	58.65	6.42	58.62	6.68	58.59	6.94	58.56	7.19	58.53	7.45	58.53	7.70	58.46	7.96	58.46
60	59.67	6.27	59.64	6.53	59.61	6.79	59.58	7.05	59.55	7.31	59.52	7.57	59.52	7.83	59.45	8.09	59.45
Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.		0 Min.	
84 Deg.		83 Degrees		81		82 Degrees		7,1									

TRAVERSE TABLE, 67.

93

6 Degrees																7 Degrees																Distance
,11								,12																								
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.																		
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.																	
61	60,67	6,38	60,64	6,64	60,61	6,91	60,58	7,17	60,55	7,43	60,51	7,70	60,48	7,96	60,44	8,23	61															
62	61,66	6,48	61,63	6,78	61,60	7,02	61,57	7,29	61,54	7,56	61,50	7,82	61,47	8,09	61,43	8,36	62															
63	62,66	6,59	62,63	6,86	62,60	7,13	62,56	7,41	62,53	7,68	62,50	7,95	62,46	8,22	62,42	8,50	63															
64	63,66	6,69	63,62	6,97	63,59	7,24	63,56	7,52	63,52	7,80	63,49	8,08	63,45	8,35	63,42	8,63	64															
65	64,64	6,80	64,61	7,08	64,58	7,36	64,55	7,64	64,52	7,92	64,48	8,20	64,44	8,48	64,41	8,77	65															
66	65,64	6,90	65,61	7,19	65,58	7,47	65,55	7,76	65,51	8,04	65,47	8,33	65,44	8,62	65,40	8,90	66															
67	66,63	7,01	66,60	7,29	66,57	7,58	66,54	7,88	66,50	8,1	66,46	8,45	66,43	8,75	66,39	9,04	67															
68	67,63	7,11	67,60	7,40	67,56	7,70	67,53	7,99	67,49	8,29	67,46	8,58	67,42	8,88	67,38	9,17	68															
69	68,62	7,21	68,59	7,51	68,56	7,81	68,52	8,11	68,49	8,41	68,45	8,71	68,41	9,01	68,37	9,31	69															
70	69,62	7,32	69,58	7,62	69,55	7,92	69,52	8,23	69,48	8,53	69,44	8,83	69,40	9,14	69,36	9,44	70															
71	70,61	7,42	70,58	7,73	70,54	8,04	70,51	8,35	70,47	8,65	70,43	8,96	70,39	9,27	70,35	9,58	71															
72	71,61	7,53	71,57	7,84	71,54	8,15	71,50	8,46	71,46	8,77	71,42	9,09	71,38	9,40	71,34	9,71	72															
73	72,60	7,63	72,57	7,95	72,53	8,26	72,49	8,58	72,46	8,90	72,42	9,21	72,37	9,53	72,33	9,84	73															
74	73,59	7,74	73,56	8,06	73,52	8,38	73,49	8,70	73,45	9,02	73,41	9,34	73,37	9,66	73,32	9,98	74															
75	74,59	7,84	74,56	8,17	74,52	8,49	74,48	8,82	74,44	9,14	74,40	9,46	74,36	9,79	74,32	10,11	75															
76	75,58	7,94	75,55	8,27	75,51	8,60	75,47	8,93	75,44	9,26	75,39	9,59	75,35	9,92	75,31	10,25	76															
77	76,58	8,05	76,54	8,38	76,51	8,72	76,47	9,05	76,43	9,38	76,38	9,72	76,34	10,05	76,30	10,38	77															
78	77,57	8,15	77,54	8,49	77,50	8,83	77,47	9,17	77,42	9,51	77,38	9,84	77,33	10,18	77,29	10,52	78															
79	78,57	8,26	78,53	8,61	78,49	8,94	78,45	9,29	78,41	9,63	78,37	9,97	78,32	10,31	78,28	10,65	79															
80	79,56	8,36	79,53	8,71	79,49	9,06	79,45	9,40	79,40	9,75	79,36	10,09	79,32	10,44	79,27	10,79	80															
81	80,56	8,47	80,52	8,82	80,48	9,17	80,44	9,52	80,39	9,87	80,35	10,22	80,31	10,57	80,26	10,92	81															
82	81,55	8,57	81,51	8,93	81,47	9,28	81,43	9,64	81,38	9,99	81,34	10,35	81,30	10,70	81,25	11,06	82															
83	82,55	8,68	82,51	9,04	82,47	9,40	82,43	9,76	82,38	10,12	82,34	10,48	82,29	10,83	82,24	11,19	83															
84	83,54	8,78	83,50	9,15	83,46	9,51	83,42	9,87	83,37	10,24	83,33	10,60	83,28	10,96	83,23	11,33	84															
85	84,53	8,88	84,50	9,25	84,45	9,62	84,41	9,99	84,37	10,36	84,32	10,73	84,27	11,10	84,22	11,46	85															
86	85,53	8,99	85,49	9,36	85,45	9,73	85,40	10,11	85,36	10,48	85,31	10,85	85,26	11,23	85,22	11,60	86															
87	86,52	9,09	86,48	9,47	86,44	9,85	86,40	10,23	86,35	10,60	86,30	10,98	86,26	11,36	86,21	11,73	87															
88	87,52	9,20	87,48	9,58	87,43	9,96	87,39	10,34	87,34	10,73	87,30	11,11	87,25	11,49	87,20	11,87	88															
89	88,51	9,30	88,47	9,69	88,43	10,07	88,38	10,46	88,34	10,85	88,29	11,23	88,24	11,62	88,19	12,00	89															
90	89,51	9,41	89,47	9,80	89,42	10,19	89,38	10,58	89,33	10,97	89,28	11,36	89,23	11,75	89,18	12,14	90															
91	90,50	9,51	90,46	9,91	90,41	10,30	90,37	10,70	90,32	11,09	90,27	11,49	90,22	11,88	90,17	12,27	91															
92	91,50	9,62	91,45	10,02	91,41	10,41	91,36	10,81	91,31	11,21	91,26	11,61	91,21	12,01	91,16	12,41	92															
93	92,49	9,72	92,45	10,13	92,40	10,53	92,36	10,93	92,31	11,33	92,26	11,74	92,20	12,14	92,15	12,54	93															
94	93,49	9,85	93,44	10,23	93,40	10,64	93,35	11,05	93,30	11,46	93,25	11,86	93,20	12,27	93,14	12,68	94															
95	94,48	9,95	94,44	10,34	94,39	10,75	94,34	11,17	94,29	11,58	94,24	11,99	94,19	12,40	94,13	12,81	95															
96	95,47	10,06	95,43	10,45	95,38	10,87	95,34	11,28	95,29	11,70	95,23	12,12	95,18	12,53	95,12	12,95	96															
97	96,47	10,14	96,42	10,56	96,38	10,98	96,33	11,40	96,28	11,81	96,22	12,24	96,17	12,66	96,11	13,08	97															
98	97,46	10,24	97,42	10,67	97,37	11,09	97,32	11,52	97,27	11,94	97,22	12,37	97,16	12,79	97,11	13,22	98															
99	98,46	10,35	98,41	10,78	98,36	11,21	98,31	11,64	98,26	12,07	98,21	12,49	98,15	12,92	98,10	13,35	99															
100	99,45	10,45	99,41	10,89	99,36	11,32	99,31	11,75	99,26	12,16	99,20	12,62	99,14	13,05	99,09	13,49	100															
101	100,4	10,56	100,4	11,00	100,4	11,43	100,3	11,87	100,2	12,31	100,2	12,75	100,1	13,18	100,1	13,62	101															
102	101,4	10,66	101,4	11,11	101,3	11,55	101,3	11,99	101,2	12,43	101,2	12,87	101,1	13,31	101,1	13,75	102															
103	102,4	10,77	102,4	11,21	102,3	11,66	102,3	12,11	102,2	12,55	102,2	13,00	102,1	13,45	102,1	13,89	103															
104	103,4	10,87	103,4	11,32	103,3	11,77	103,3	12,22	103,2	12,68	103,2	13,13	103,1	13,58	103,1	14,02	104															
105	104,4	10,98	104,4	11,43	104,3	11,89	104,3	12,34	104,2	12,80	104,2	13,26	104,1	13,71	104,0	14,16	105															
106	105,4	11,08	105,4	11,54	105,3	12,00	105,3	12,46	105,2	12,92	105,2	13,38	105,1	13,84	105,0	14,30	106															
107	106,4	11,18	106,4	11,65	106,3	12,11	106,3	12,58	106,2	13,04	106,1	13,50	106,1	13,97	106,0	14,43	107															
108	107,4	11,29	107,4	11,76	107,3	12,23	107,3	12,69	107,2	13,16	107,1	13,63	107,1	14,10	107,0	14,56	108															
109	108,4	11,39	108,3	11,87	108,3	12,34	108,2	12,81	108,2	13,28	108,1	13,76	108,1	14,23	108,0	14,70	109															
110	109,4	11,50	109,3	11,98	109,3	12,45	109,2	12,93	109,2	13,41	109,1	13,88	109,0	14,36	109,0	14,83	110															
111	110,4	11,60	110,3	12,08	110,3	12,57	110,2	13,05	110,2	13,53	110,1	14,01	110,0	14,49	110,0	14,97	111															
112	111,4	11,71	111,3	12,19	111,3	12,68	111,2	13,16	111,2	13,65	111,1	14,14	111,0	14,62	111,0	15,10	112															
113	112,4	11,81	112,3	12,30	112,3	12,79	112,2	13,28	112,2	13,77	112,1	14,26	112,0	14,75	112,0	15,24	113															
114	113,4	11,92	113,3	12,41	113,3	12,90	113,2	13,40	113,1	13,89	113,1	14,39	113,0	14,88	113,0	15,37	114															
115	114,4	12,02	114,3	12,52	114,3	13,02	114,2	13,52	114,1	14,01	114,1	14,51	114,0	15,01	114,0	15,51	115															
116	115,4	12,13	115,3	12,63	115,3	13,13	115,2	13,63	115,1	14,14	115,1	14,64	115,0	15,14	115,0	15,64	116															
117	116,4	12,23	116,3	12,74	116,2	13,24	116,2	13,75	116,1	14,26	116,1	14,76	116,0	15,27	116,0	15,78	117															
118	117,4	12,33	117,3	12,85	117,2	13,36	117,2	13,87	117,1	14,38	117,1	14,89	117,0	15,40	117,0	15,91	118															
119	118,4	12,44	118,3	12,95	118,2	13,47	118,2	13,99	118,1	14,50	118,0	15,02	118,0	15,53	118,0	16,05	119															
120	119,3	12,54	119,3	13,06	119,2	13,58	119,2	14,11	119,1	14,62	119,0	15,17	119,0	15,66	119,0	16,18	120															
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.																					

Distance	8 Degrees								9 Degrees							
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	0,99	0,14	0,99	0,14	0,99	0,15	0,99	0,15	0,99	0,16	0,99	0,16	0,99	0,17	0,99	0,17
2	1,98	0,28	1,98	0,29	1,98	0,30	1,98	0,30	1,98	0,31	1,97	0,32	1,97	0,33	1,97	0,34
3	2,97	0,42	2,97	0,43	2,97	0,44	2,97	0,46	2,96	0,47	2,96	0,48	2,96	0,50	2,96	0,51
4	3,96	0,56	3,96	0,57	3,96	0,59	3,95	0,61	3,95	0,63	3,95	0,64	3,95	0,66	3,94	0,68
5	4,95	0,70	4,95	0,72	4,95	0,74	4,94	0,76	4,94	0,78	4,94	0,80	4,93	0,83	4,92	0,85
6	5,94	0,84	5,94	0,86	5,93	0,88	5,93	0,91	5,93	0,94	5,92	0,96	5,92	0,99	5,91	1,02
7	6,93	0,97	6,93	1,00	6,92	1,04	6,92	1,07	6,91	1,10	6,91	1,13	6,90	1,16	6,89	1,19
8	7,92	1,11	7,92	1,15	7,91	1,18	7,91	1,22	7,90	1,25	7,90	1,29	7,89	1,32	7,88	1,36
9	8,91	1,25	8,91	1,29	8,90	1,33	8,90	1,37	8,89	1,41	8,88	1,45	8,88	1,49	8,86	1,52
10	9,90	1,39	9,90	1,44	9,89	1,48	9,88	1,52	9,88	1,56	9,87	1,61	9,86	1,65	9,85	1,70
11	10,89	1,53	10,89	1,58	10,88	1,63	10,87	1,67	10,87	1,72	10,86	1,77	10,85	1,82	10,84	1,86
12	11,88	1,67	11,88	1,72	11,87	1,77	11,86	1,83	11,85	1,88	11,84	1,93	11,84	1,98	11,83	2,03
13	12,87	1,81	12,87	1,87	12,86	1,92	12,85	1,98	12,84	2,03	12,83	2,09	12,82	2,15	12,81	2,20
14	13,86	1,95	13,86	2,01	13,85	2,07	13,84	2,13	13,83	2,19	13,82	2,25	13,81	2,31	13,79	2,37
15	14,85	2,09	14,85	2,15	14,84	2,22	14,83	2,28	14,82	2,35	14,81	2,41	14,79	2,48	14,78	2,54
16	15,84	2,23	15,84	2,30	15,82	2,37	15,81	2,43	15,80	2,50	15,79	2,57	15,78	2,64	15,77	2,71
17	16,83	2,37	16,83	2,44	16,81	2,51	16,80	2,59	16,79	2,66	16,78	2,73	16,77	2,81	16,75	2,88
18	17,82	2,51	17,81	2,58	17,80	2,66	17,79	2,74	17,78	2,82	17,77	2,89	17,75	2,97	17,74	3,05
19	18,81	2,64	18,80	2,73	18,79	2,81	18,78	2,89	18,77	2,97	18,75	3,05	18,74	3,14	18,73	3,22
20	19,81	2,78	19,79	2,87	19,78	2,96	19,77	3,04	19,75	3,13	19,74	3,22	19,73	3,30	19,71	3,39
21	20,79	2,92	20,78	3,01	20,77	3,10	20,76	3,19	20,74	3,29	20,73	3,38	20,71	3,47	20,70	3,55
22	21,78	3,06	21,77	3,16	21,76	3,25	21,74	3,35	21,73	3,44	21,71	3,54	21,70	3,63	21,68	3,73
23	22,77	3,21	22,76	3,30	22,75	3,40	22,73	3,50	22,72	3,60	22,70	3,70	22,69	3,80	22,67	3,90
24	23,76	3,34	23,75	3,44	23,74	3,55	23,72	3,65	23,71	3,76	23,69	3,86	23,67	3,96	23,65	4,07
25	24,75	3,48	24,74	3,59	24,73	3,70	24,71	3,80	24,69	3,91	24,68	4,02	24,66	4,13	24,64	4,24
26	25,74	3,62	25,73	3,73	25,71	3,84	25,70	3,95	25,68	4,07	25,66	4,18	25,64	4,29	25,62	4,40
27	26,73	3,76	26,72	3,87	26,70	3,99	26,69	4,11	26,67	4,22	26,65	4,34	26,63	4,46	26,61	4,57
28	27,72	3,90	27,71	4,02	27,69	4,14	27,67	4,26	27,66	4,38	27,64	4,50	27,61	4,62	27,60	4,74
29	28,71	4,04	28,70	4,16	28,68	4,29	28,66	4,41	28,64	4,54	28,62	4,66	28,60	4,79	28,58	4,91
30	29,71	4,18	29,69	4,31	29,67	4,43	29,65	4,56	29,63	4,69	29,61	4,82	29,59	4,96	29,57	5,08
31	30,70	4,31	30,68	4,45	30,66	4,58	30,64	4,72	30,62	4,85	30,60	4,98	30,58	5,12	30,55	5,25
32	31,69	4,45	31,67	4,59	31,65	4,73	31,63	4,87	31,61	5,01	31,58	5,14	31,56	5,29	31,54	5,42
33	32,68	4,59	32,66	4,74	32,64	4,88	32,62	5,02	32,59	5,16	32,57	5,31	32,55	5,45	32,52	5,59
34	33,67	4,73	33,65	4,88	33,63	5,03	33,61	5,17	33,58	5,32	33,56	5,47	33,53	5,62	33,51	5,77
35	34,66	4,87	34,64	5,02	34,62	5,17	34,59	5,33	34,57	5,48	34,55	5,63	34,52	5,78	34,49	5,93
36	35,65	5,01	35,63	5,17	35,61	5,32	35,58	5,48	35,56	5,63	35,54	5,79	35,51	5,95	35,48	6,10
37	36,64	5,15	36,62	5,31	36,59	5,47	36,57	5,63	36,55	5,79	36,53	5,95	36,49	6,11	36,47	6,27
38	37,63	5,29	37,61	5,45	37,58	5,62	37,56	5,78	37,53	5,95	37,51	6,11	37,48	6,28	37,45	6,44
39	38,62	5,43	38,60	5,60	38,57	5,76	38,55	5,93	38,52	6,10	38,49	6,27	38,47	6,44	38,44	6,61
40	39,61	5,57	39,59	5,74	39,56	5,91	39,53	6,09	39,51	6,26	39,48	6,43	39,45	6,61	39,42	6,78
41	40,60	5,71	40,58	5,88	40,55	6,06	40,52	6,24	40,50	6,41	40,47	6,59	40,44	6,77	40,41	6,94
42	41,59	5,85	41,57	6,03	41,54	6,21	41,51	6,39	41,48	6,57	41,45	6,75	41,43	6,94	41,39	7,11
43	42,58	5,99	42,56	6,17	42,53	6,36	42,50	6,54	42,47	6,73	42,44	6,91	42,41	7,10	42,38	7,28
44	43,57	6,12	43,55	6,31	43,52	6,50	43,49	6,69	43,46	6,88	43,43	7,07	43,40	7,27	43,36	7,45
45	44,56	6,26	44,54	6,46	44,51	6,65	44,48	6,85	44,45	7,04	44,42	7,23	44,38	7,43	44,35	7,62
46	45,55	6,40	45,52	6,60	45,50	6,80	45,46	7,00	45,43	7,20	45,40	7,40	45,37	7,60	45,34	7,79
47	46,54	6,54	46,51	6,74	46,48	6,95	46,45	7,15	46,42	7,35	46,39	7,56	46,36	7,76	46,32	7,96
48	47,53	6,68	47,50	6,89	47,47	7,09	47,44	7,30	47,41	7,51	47,38	7,72	47,34	7,93	47,31	8,13
49	48,52	6,82	48,49	7,03	48,46	7,24	48,43	7,45	48,40	7,66	48,36	7,88	48,33	8,09	48,29	8,30
50	49,51	6,96	49,48	7,18	49,45	7,39	49,42	7,61	49,39	7,82	49,35	8,04	49,32	8,26	49,28	8,47
51	50,50	7,10	50,47	7,32	50,44	7,54	50,41	7,76	50,37	7,98	50,34	8,20	50,30	8,42	50,26	8,64
52	51,49	7,24	51,46	7,46	51,43	7,69	51,40	7,91	51,36	8,14	51,32	8,36	51,29	8,59	51,25	8,81
53	52,48	7,38	52,45	7,61	52,42	7,83	52,38	8,06	52,35	8,29	52,31	8,52	52,27	8,75	52,24	8,98
54	53,47	7,52	53,44	7,75	53,41	7,98	53,37	8,21	53,34	8,45	53,30	8,68	53,26	8,92	53,22	9,15
55	54,47	7,66	54,43	7,89	54,40	8,13	54,36	8,37	54,32	8,60	54,29	8,84	54,25	9,08	54,21	9,32
56	55,46	7,79	55,42	8,04	55,39	8,28	55,35	8,52	55,31	8,76	55,27	9,00	55,23	9,25	55,19	9,48
57	56,45	7,93	56,41	8,18	56,37	8,43	56,34	8,67	56,30	8,92	56,26	9,16	56,22	9,41	56,18	9,68
58	57,44	8,07	57,40	8,32	57,36	8,57	57,33	8,82	57,29	9,07	57,25	9,32	57,21	9,58	57,16	9,82
59	58,43	8,21	58,39	8,47	58,35	8,72	58,31	8,98	58,28	9,23	58,23	9,48	58,18	9,74	58,15	9,99
60	59,42	8,35	59,38	8,61	59,34	8,87	59,30	9,13	59,26	9,39	59,22	9,62	59,18	9,97	59,13	10,16
Distance	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.	
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	82 Deg.		81 Degrees		6,3		80 Degrees		5,7							

TRAVERSE TABLE, 67.

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8 Degrees																9 Degrees																Distance	
14								16																									
0 Min.				15 Min.				30 Min.				45 Min.				0 Min.				15 Min.				30 Min.				45 Min.					
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
60,41	8,49	60,37	8,75	60,33	9,02	60,29	9,28	60,25	9,54	60,21	9,81	60,16	10,07	60,12	10,33	60,11	10,50	60,10	10,67	60,09	10,84	60,08	11,01	60,07	11,18	60,06	11,35	60,05	11,52	60,04	12,09	61	
61,40	8,63	61,36	8,90	61,32	9,16	61,28	9,43	61,24	9,70	61,19	9,97	61,15	10,24	61,11	10,50	61,10	10,67	61,09	10,84	61,08	11,01	61,07	11,18	61,06	11,35	61,05	11,52	61,04	12,09	61,03	12,26	62	
62,39	8,77	62,35	9,04	62,31	9,31	62,27	9,58	62,22	9,86	62,18	10,13	62,14	10,40	62,09	10,67	62,08	10,84	62,07	11,01	62,06	11,18	62,05	11,35	62,04	11,52	62,03	12,09	62,02	12,26	62,01	12,43	63	
63,38	8,91	63,34	9,18	63,30	9,46	63,26	9,74	63,21	10,01	63,17	10,29	63,12	10,57	63,08	10,84	63,07	11,01	63,06	11,18	63,05	11,35	63,04	11,52	63,03	12,09	63,02	12,26	63,01	12,43	63,00	12,60	64	
64,37	9,05	64,33	9,33	64,29	9,61	64,24	9,89	64,20	10,17	64,16	10,45	64,11	10,74	64,06	11,01	64,05	11,18	64,04	11,35	64,03	11,52	64,02	12,09	64,01	12,26	64,00	12,43	64,00	12,60	64,00	12,77	65	
65,36	9,19	65,32	9,47	65,28	9,76	65,23	10,04	65,19	10,33	65,14	10,61	65,09	10,90	65,05	11,18	65,04	11,35	65,03	11,52	65,02	12,09	65,01	12,26	65,00	12,43	65,00	12,60	65,00	12,77	65,00	12,94	66	
66,35	9,32	66,31	9,61	66,26	9,90	66,22	10,19	66,18	10,48	66,13	10,77	66,08	11,07	66,03	11,35	66,02	11,52	66,01	12,09	66,00	12,26	66,00	12,43	66,00	12,60	66,00	12,77	66,00	12,94	66,00	13,11	67	
67,34	9,46	67,30	9,76	67,25	10,05	67,21	10,34	67,16	10,64	67,12	10,93	67,07	11,23	67,02	11,52	67,01	12,09	67,00	12,26	67,00	12,43	67,00	12,60	67,00	12,77	67,00	12,94	67,00	13,11	67,00	13,28	68	
68,33	9,60	68,29	9,90	68,24	10,20	68,20	10,50	68,15	10,79	68,10	11,09	68,05	11,40	68,00	11,69	68,00	12,09	68,00	12,26	68,00	12,43	68,00	12,60	68,00	12,77	68,00	12,94	68,00	13,11	68,00	13,28	69	
69,32	9,74	69,28	10,04	69,23	10,35	69,19	10,65	69,14	10,95	69,09	11,25	69,04	11,56	69,00	11,86	69,00	12,26	69,00	12,43	69,00	12,60	69,00	12,77	69,00	12,94	69,00	13,11	69,00	13,28	69,00	13,45	70	
70,31	9,88	70,27	10,19	70,22	10,50	70,17	10,80	70,13	11,11	70,08	11,41	70,03	11,73	70,00	12,02	70,00	12,26	70,00	12,43	70,00	12,60	70,00	12,77	70,00	12,94	70,00	13,11	70,00	13,28	70,00	13,45	71	
71,30	10,02	71,26	10,33	71,21	10,64	71,16	10,95	71,11	11,26	71,06	11,57	71,01	11,89	71,00	12,21	71,00	12,43	71,00	12,60	71,00	12,77	71,00	12,94	71,00	13,11	71,00	13,28	71,00	13,45	71,00	13,62	72	
72,29	10,16	72,25	10,47	72,20	10,79	72,15	11,10	72,10	11,42	72,05	11,74	72,00	12,06	72,00	12,38	72,00	12,60	72,00	12,77	72,00	12,94	72,00	13,11	72,00	13,28	72,00	13,45	72,00	13,62	72,00	13,79	73	
73,28	10,30	73,23	10,62	73,19	10,94	73,14	11,26	73,09	11,58	73,04	11,90	73,00	12,22	73,00	12,54	73,00	12,77	73,00	12,94	73,00	13,11	73,00	13,28	73,00	13,45	73,00	13,62	73,00	13,79	73,00	13,96	74	
74,27	10,44	74,22	10,76	74,18	11,09	74,13	11,41	74,08	11,73	74,03	12,06	74,00	12,39	74,00	12,71	74,00	13,04	74,00	13,36	74,00	13,68	74,00	14,00	74,00	14,32	74,00	14,64	74,00	14,96	74,00	15,28	75	
75,26	10,58	75,21	10,91	75,17	11,24	75,11	11,56	75,07	11,89	75,01	12,22	75,00	12,55	75,00	12,87	75,00	13,19	75,00	13,52	75,00	13,84	75,00	14,17	75,00	14,49	75,00	14,82	75,00	15,14	75,00	15,47	76	
76,25	10,72	76,20	11,05	76,15	11,38	76,10	11,71	76,05	12,05	76,00	12,38	76,00	12,72	76,00	13,04	76,00	13,38	76,00	13,71	76,00	14,04	76,00	14,37	76,00	14,69	76,00	15,02	76,00	15,35	76,00	15,68	77	
77,24	10,86	77,19	11,19	77,14	11,53	77,09	11,86	77,04	12,20	77,00	12,54	77,00	12,88	77,00	13,21	77,00	13,54	77,00	13,87	77,00	14,20	77,00	14,53	77,00	14,86	77,00	15,19	77,00	15,52	77,00	15,85	78	
78,23	10,99	78,18	11,34	78,13	11,68	78,08	12,02	78,03	12,36	78,00	12,70	78,00	13,05	78,00	13,38	78,00	13,71	78,00	14,04	78,00	14,37	78,00	14,70	78,00	15,03	78,00	15,36	78,00	15,69	78,00	16,02	79	
79,22	11,13	79,17	11,48	79,12	11,83	79,07	12,17	79,02	12,51	79,00	12,86	79,00	13,21	79,00	13,55	79,00	13,89	79,00	14,23	79,00	14,57	79,00	14,91	79,00	15,25	79,00	15,59	79,00	15,93	79,00	16,27	80	
80,21	11,27	80,16	11,62	80,11	11,97	80,06	12,32	80,00	12,67	80,00	13,02	80,00	13,38	80,00	13,72	80,00	14,06	80,00	14,40	80,00	14,74	80,00	15,08	80,00	15,42	80,00	15,76	80,00	16,10	80,00	16,44	81	
81,20	11,41	81,15	11,77	81,10	12,12	81,05	12,47	81,00	12,83	81,00	13,18	81,00	13,54	81,00	13,89	81,00	14,23	81,00	14,57	81,00	14,91	81,00	15,25	81,00	15,59	81,00	15,93	81,00	16,27	81,00	16,61	82	
82,19	11,55	82,14	11,91	82,09	12,27	82,03	12,63	82,00	13,00	82,00	13,36	82,00	13,72	82,00	14,08	82,00	14,44	82,00	14,79	82,00	15,15	82,00	15,51	82,00	15,87	82,00	16,23	82,00	16,59	82,00	16,95	83	
83,18	11,69	83,13	12,05	83,08	12,42	83,02	12,78	83,00	13,14	83,00	13,50	83,00	13,86	83,00	14,23	83,00	14,59	83,00	14,95	83,00	15,31	83,00	15,67	83,00	16,03	83,00	16,39	83,00	16,75	83,00	17,11	84	
84,17	11,83	84,12	12,20	84,07	12,56	84,01	12,93	84,00	13,30	84,00	13,66	84,00	14,02	84,00	14,39	84,00	14,75	84,00	15,11	84,00	15,47	84,00	15,83	84,00	16,19	84,00	16,55	84,00	16,91	84,00	17,27	85	
85,16	11,97	85,11	12,34	85,06	12,72	85,00	13,08	85,00	13,45	85,00	13,82	85,00	14,18	85,00	14,55	85,00	14,91	85,00	15,27	85,00	15,63	85,00	16,00	85,00	16,36	85,00	16,72	85,00	17,08	85,00	17,44	86	
86,15	12,11	86,10	12,48	86,05	12,86	86,00	13,23	86,00	13,61	86,00	13,99	86,00	14,37	86,00	14,73	86,00	15,10	86,00	15,46	86,00	15,83	86,00	16,19	86,00	16,55	86,00	16,91	86,00	17,27	86,00	17,63	87	
87,14	12,25	87,09	12,63	87,03	13,01	87,00	13,39	87,00	13,77	87,00	14,15	87,00	14,53	87,00	14,90	87,00	15,27	87,00	15,64	87,00	16,01	87,00	16,38	87,00	16,75	87,00	17,11	87,00	17,48	87,00	17,85	88	
88,13	12,39	88,08	12,77	88,02	13,16	88,00	13,54	88,00	13,92	88,00	14,31	88,00	14,69	88,00	15,07	88,00	15,45	88,00	15,83	88,00	16,21	88,00	16,59	88,00	16,97	88,00	17,35	88,00	17,73	88,00	18,11	89	
89,12	12,53	89,07	12,91	89,01	13,30	89,00	13,69	89,00	14,08	89,00	14,47	89,00	14,86	89,00	15,24	89,00	15,63	89,00	16,02	89,00	16,41	89,00	16,79	89,00	17,18	89,00	17,57	89,00	17,96	89,00	18,35	90	
90,11	12,67	90,06	13,06	90,00	13,45	90,00	13,84	90,00	14,24	90,00	14,63	90,00	15,03	90,00	15,41	90,00	15,80	90,00	16,19	90,00	16,58	90,00	16,97	90,00	17,36	90,00	17,75	90,00	18,14	90,00	18,53	91	
91,10	12,80	91,05																															

Distance	10 Degrees								11 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	0 Min.	15 Min.	30 Min.	45 Min.	0 Min.	15 Min.	30 Min.	45 Min.	0 Min.	15 Min.	30 Min.	45 Min.	0 Min.	15 Min.	30 Min.	45 Min.	
1	0,98	0,17	0,98	0,18	0,98	0,18	0,98	0,19	0,98	0,19	0,98	0,20	0,98	0,20	0,98	0,20	
2	1,97	0,35	1,97	0,36	1,97	0,36	1,97	0,37	1,96	0,38	1,96	0,39	1,96	0,40	1,96	0,40	
3	2,95	0,52	2,95	0,53	2,95	0,53	2,95	0,56	2,95	0,57	2,94	0,59	2,94	0,60	2,94	0,60	
4	3,94	0,70	3,94	0,71	3,93	0,73	3,93	0,75	3,93	0,76	3,92	0,78	3,92	0,80	3,92	0,80	
5	4,92	0,87	4,92	0,89	4,92	0,91	4,91	0,93	4,91	0,95	4,90	0,98	4,90	1,00	4,90	1,00	
6	5,91	1,04	5,90	1,07	5,90	1,09	5,90	1,12	5,89	1,15	5,89	1,17	5,88	1,20	5,87	1,22	
7	6,89	1,22	6,89	1,25	6,88	1,28	6,88	1,31	6,87	1,34	6,87	1,37	6,86	1,40	6,85	1,42	
8	7,88	1,39	7,87	1,42	7,87	1,46	7,86	1,49	7,85	1,53	7,85	1,56	7,84	1,60	7,83	1,62	
9	8,86	1,56	8,86	1,60	8,85	1,64	8,84	1,68	8,84	1,72	8,83	1,76	8,82	1,79	8,81	1,82	
10	9,85	1,74	9,84	1,78	9,83	1,82	9,83	1,87	9,82	1,91	9,81	1,95	9,80	1,99	9,79	2,02	
11	10,83	1,91	10,82	1,96	10,82	2,01	10,81	2,05	10,80	2,10	10,79	2,15	10,78	2,19	10,77	2,24	
12	11,82	2,08	11,81	2,14	11,80	2,19	11,79	2,24	11,78	2,29	11,77	2,34	11,76	2,39	11,75	2,44	
13	12,80	2,26	12,79	2,31	12,78	2,37	12,77	2,43	12,76	2,48	12,75	2,54	12,74	2,59	12,73	2,64	
14	13,78	2,43	13,78	2,49	13,77	2,55	13,75	2,61	13,74	2,67	13,73	2,73	13,72	2,79	13,71	2,85	
15	14,77	2,61	14,76	2,67	14,75	2,73	14,74	2,80	14,73	2,86	14,71	2,93	14,70	2,99	14,69	3,05	
16	15,76	2,78	15,74	2,85	15,73	2,92	15,72	2,98	15,71	3,05	15,69	3,12	15,68	3,19	15,67	3,25	
17	16,74	2,95	16,73	3,03	16,72	3,11	16,70	3,17	16,69	3,24	16,67	3,32	16,66	3,39	16,64	3,46	
18	17,73	3,13	17,71	3,20	17,70	3,28	17,68	3,36	17,67	3,43	17,65	3,51	17,64	3,59	17,62	3,66	
19	18,71	3,30	18,70	3,38	18,69	3,46	18,67	3,54	18,65	3,63	18,64	3,71	18,62	3,79	18,60	3,87	
20	19,70	3,47	19,68	3,56	19,67	3,65	19,65	3,73	19,63	3,82	19,62	3,90	19,60	3,99	19,58	4,07	
21	20,68	3,65	20,67	3,74	20,65	3,83	20,63	3,92	20,61	4,01	20,60	4,10	20,58	4,19	20,56	4,28	
22	21,67	3,82	21,65	3,92	21,63	4,01	21,61	4,10	21,60	4,20	21,58	4,29	21,56	4,39	21,54	4,48	
23	22,65	3,99	22,63	4,09	22,61	4,19	22,60	4,29	22,58	4,39	22,56	4,49	22,54	4,59	22,52	4,68	
24	23,64	4,17	23,62	4,27	23,60	4,37	23,58	4,48	23,56	4,58	23,54	4,68	23,52	4,78	23,50	4,88	
25	24,62	4,34	24,60	4,45	24,58	4,56	24,56	4,66	24,54	4,77	24,52	4,88	24,50	4,98	24,48	5,08	
26	25,61	4,51	25,59	4,63	25,56	4,74	25,54	4,85	25,52	4,96	25,50	5,07	25,48	5,18	25,46	5,28	
27	26,59	4,69	26,57	4,81	26,55	4,92	26,53	5,04	26,50	5,15	26,48	5,27	26,46	5,38	26,44	5,48	
28	27,57	4,86	27,55	4,98	27,53	5,10	27,51	5,22	27,49	5,34	27,46	5,46	27,44	5,58	27,42	5,68	
29	28,56	5,04	28,54	5,16	28,51	5,29	28,49	5,41	28,47	5,53	28,44	5,66	28,42	5,78	28,39	5,90	
30	29,54	5,21	29,52	5,34	29,50	5,47	29,47	5,60	29,45	5,72	29,42	5,85	29,40	5,98	29,37	6,11	
31	30,53	5,38	30,51	5,52	30,48	5,65	30,46	5,78	30,43	5,92	30,41	6,05	30,38	6,18	30,35	6,31	
32	31,51	5,56	31,49	5,69	31,46	5,83	31,44	5,97	31,41	6,11	31,39	6,24	31,36	6,38	31,33	6,52	
33	32,50	5,73	32,47	5,87	32,45	6,01	32,42	6,16	32,39	6,30	32,37	6,44	32,34	6,58	32,31	6,72	
34	33,48	5,91	33,46	6,05	33,43	6,20	33,40	6,34	33,38	6,49	33,35	6,63	33,32	6,78	33,29	6,92	
35	34,47	6,08	34,44	6,23	34,41	6,38	34,39	6,53	34,36	6,68	34,33	6,83	34,30	6,98	34,27	7,13	
36	35,45	6,25	35,43	6,41	35,40	6,56	35,37	6,72	35,34	6,87	35,31	7,02	35,28	7,18	35,25	7,33	
37	36,44	6,43	36,41	6,58	36,38	6,74	36,35	6,90	36,32	7,06	36,29	7,22	36,26	7,38	36,23	7,53	
38	37,42	6,60	37,39	6,76	37,36	6,93	37,33	7,09	37,30	7,25	37,27	7,41	37,24	7,58	37,21	7,74	
39	38,41	6,77	38,38	6,94	38,35	7,11	38,32	7,28	38,28	7,44	38,25	7,61	38,22	7,78	38,18	7,94	
40	39,39	6,95	39,36	7,12	39,33	7,29	39,30	7,46	39,27	7,63	39,23	7,80	39,20	7,98	39,16	8,14	
41	40,38	7,12	40,35	7,30	40,31	7,47	40,28	7,65	40,25	7,82	40,21	8,00	40,18	8,17	40,14	8,34	
42	41,36	7,29	41,33	7,47	41,30	7,65	41,26	7,83	41,23	8,01	41,19	8,19	41,16	8,37	41,12	8,52	
43	42,35	7,47	42,31	7,65	42,28	7,84	42,25	8,02	42,21	8,20	42,17	8,39	42,14	8,57	42,10	8,75	
44	43,33	7,64	43,30	7,83	43,26	8,02	43,23	8,21	43,19	8,40	43,16	8,58	43,12	8,77	43,08	8,95	
45	44,32	7,81	44,28	8,01	44,25	8,20	44,21	8,39	44,17	8,59	44,14	8,78	44,10	8,97	44,06	9,14	
46	45,30	7,99	45,27	8,19	45,23	8,38	45,19	8,58	45,16	8,78	45,12	8,97	45,08	9,17	45,04	9,37	
47	46,29	8,16	46,25	8,36	46,21	8,57	46,18	8,77	46,14	8,97	46,10	9,17	46,06	9,37	46,02	9,57	
48	47,27	8,33	47,23	8,54	47,20	8,75	47,16	8,95	47,12	9,16	47,08	9,37	47,04	9,57	47,00	9,78	
49	48,26	8,51	48,22	8,72	48,18	8,93	48,14	9,14	48,10	9,35	48,06	9,56	48,02	9,77	47,97	9,98	
50	49,24	8,68	49,20	8,90	49,16	9,11	49,12	9,33	49,08	9,54	49,04	9,76	49,00	9,97	48,95	10,18	
51	50,23	8,86	50,19	9,08	50,15	9,29	50,11	9,51	50,06	9,73	50,02	9,95	49,98	10,17	49,93	10,39	
52	51,21	9,03	51,17	9,25	51,13	9,48	51,09	9,70	51,05	9,92	51,00	10,15	50,96	10,37	50,91	10,59	
53	52,20	9,20	52,15	9,43	52,11	9,66	52,07	9,89	52,03	10,11	51,98	10,34	51,94	10,57	51,89	10,79	
54	53,18	9,38	53,14	9,61	53,10	9,84	53,05	10,07	53,01	10,30	52,96	10,54	52,92	10,77	52,87	11,00	
55	54,17	9,55	54,12	9,79	54,08	10,02	54,04	10,26	53,99	10,50	53,94	10,73	53,90	10,97	53,85	11,20	
56	55,15	9,72	55,11	9,97	55,06	10,21	55,02	10,45	54,97	10,69	54,93	10,93	54,88	11,17	54,83	11,40	
57	56,14	9,90	56,09	10,14	56,05	10,39	56,00	10,63	55,95	10,88	55,91	11,12	55,86	11,37	55,81	11,61	
58	57,12	10,07	57,07	10,32	57,03	10,57	56,98	10,82	56,94	11,07	56,89	11,32	56,84	11,56	56,79	11,81	
59	58,10	10,25	58,06	10,50	58,01	10,75	57,97	11,01	57,92	11,26	57,87	11,51	57,82	11,76	57,77	12,02	
60	59,09	10,42	59,04	10,68	58,99	10,93	58,95	11,19	58,90	11,45	58,85	11,71	58,80	11,96	58,74	12,22	
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.		
	80 Degrees																

TRAVERSE TABLE, 67.

97

10 Degrees										11 Degrees										12 Degrees									
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.							
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.						
61	60,07	10,59	60,03	10,85	59,98	11,12	59,93	11,38	59,88	11,64	59,83	11,90	59,78	12,16	59,72	12,41	59,67	12,67	59,62	12,93	59,57	13,19	59,52						
62	61,06	10,77	61,01	11,03	60,96	11,30	60,91	11,56	60,86	11,83	60,81	12,09	60,76	12,36	60,70	12,63	60,65	12,90	60,60	13,17	60,55	13,44	60,50						
63	62,04	10,94	61,99	11,21	61,94	11,48	61,89	11,75	61,84	12,02	61,79	12,29	61,74	12,56	61,68	12,83	61,63	13,10	61,58	13,37	61,53	13,64	61,48						
64	63,03	11,11	62,98	11,39	62,93	11,66	62,88	11,94	62,83	12,21	62,77	12,49	62,72	12,76	62,66	13,03	62,61	13,30	62,56	13,57	62,51	13,84	62,46						
65	64,01	11,29	63,96	11,57	63,91	11,85	63,86	12,12	63,81	12,40	63,75	12,68	63,70	12,96	63,64	13,21	63,59	13,48	63,54	13,75	63,49	14,02	63,44						
66	65,00	11,46	64,95	11,74	64,89	12,03	64,84	12,31	64,79	12,59	64,73	12,88	64,68	13,16	64,62	13,44	64,57	13,71	64,52	13,98	64,47	14,25	64,42						
67	65,98	11,64	65,93	11,92	65,88	12,21	65,82	12,50	65,77	12,79	65,71	13,07	65,66	13,36	65,60	13,64	65,55	13,91	65,50	14,18	65,45	14,45	65,40						
68	66,97	11,81	66,91	12,10	66,86	12,39	66,81	12,68	66,75	12,98	66,69	13,27	66,64	13,56	66,58	13,85	66,53	14,12	66,48	14,40	66,43	14,67	66,38						
69	67,95	11,98	67,90	12,28	67,84	12,57	67,79	12,87	67,73	13,17	67,67	13,46	67,61	13,76	67,55	14,05	67,50	14,32	67,45	14,60	67,40	14,87	67,35						
70	68,94	12,16	68,88	12,46	68,83	12,76	68,77	13,06	68,71	13,36	68,66	13,66	68,59	13,96	68,53	14,26	68,48	14,53	68,43	14,80	68,38	15,07	68,33						
71	69,92	12,38	69,87	12,63	69,81	12,94	69,75	13,24	69,70	13,55	69,64	13,85	69,57	14,16	69,51	14,46	69,46	14,73	69,41	15,00	69,36	15,27	69,31						
72	70,91	12,50	70,85	12,81	70,79	13,12	70,74	13,43	70,68	13,74	70,62	14,05	70,55	14,36	70,49	14,66	70,44	14,93	70,39	15,20	70,34	15,47	70,29						
73	71,89	12,68	71,84	12,99	71,77	13,30	71,72	13,61	71,66	13,93	71,60	14,24	71,53	14,55	71,47	14,87	71,42	15,14	71,37	15,41	71,32	15,68	71,27						
74	72,88	12,85	72,82	13,17	72,76	13,49	72,70	13,80	72,64	14,12	72,58	14,44	72,51	14,75	72,45	15,07	72,40	15,34	72,35	15,61	72,30	15,88	72,25						
75	73,86	13,02	73,80	13,35	73,74	13,67	73,68	13,99	73,62	14,31	73,56	14,63	73,49	14,95	73,43	15,27	73,38	15,54	73,33	15,81	73,28	16,08	73,23						
76	74,85	13,20	74,79	13,52	74,73	13,85	74,67	14,18	74,60	14,50	74,54	14,83	74,47	15,15	74,41	15,48	74,36	15,75	74,31	16,02	74,26	16,29	74,21						
77	75,83	13,37	75,77	13,70	75,71	14,03	75,65	14,36	75,59	14,69	75,52	15,02	75,45	15,35	75,39	15,68	75,34	15,95	75,29	16,22	75,24	16,49	75,19						
78	76,82	13,54	76,76	13,88	76,69	14,22	76,63	14,55	76,57	14,88	76,50	15,22	76,43	15,55	76,37	15,88	76,32	16,15	76,27	16,42	76,22	16,67	76,17						
79	77,80	13,72	77,74	14,06	77,68	14,40	77,61	14,74	77,55	15,07	77,48	15,41	77,41	15,75	77,35	16,09	77,30	16,36	77,25	16,61	77,20	16,86	77,15						
80	78,79	13,89	78,72	14,24	78,66	14,58	78,60	14,92	78,53	15,27	78,46	15,61	78,39	15,95	78,32	16,29	78,27	16,55	78,22	16,81	78,17	17,06	78,12						
81	79,77	14,07	79,71	14,41	79,64	14,76	79,58	15,11	79,51	15,46	79,44	15,80	79,37	16,15	79,30	16,50	79,25	16,76	79,20	17,01	79,15	17,26	79,10						
82	80,76	14,24	80,69	14,59	80,63	14,94	80,56	15,30	80,49	15,65	80,43	16,00	80,35	16,35	80,28	16,70	80,23	16,96	80,18	17,21	80,13	17,46	80,08						
83	81,74	14,41	81,68	14,77	81,61	15,13	81,54	15,48	81,48	15,84	81,41	16,19	81,33	16,55	81,26	16,90	81,21	17,16	81,16	17,41	81,11	17,66	81,06						
84	82,73	14,59	82,66	14,95	82,59	15,31	82,53	15,67	82,46	16,03	82,39	16,39	82,31	16,75	82,24	17,11	82,19	17,36	82,14	17,61	82,09	17,86	82,04						
85	83,72	14,76	83,64	15,13	83,58	15,49	83,51	15,86	83,44	16,22	83,37	16,58	83,29	16,95	83,22	17,31	83,17	17,56	83,12	17,83	83,07	18,08	83,02						
86	84,71	14,93	84,63	15,30	84,56	15,67	84,49	16,04	84,42	16,41	84,35	16,78	84,27	17,15	84,20	17,51	84,15	17,76	84,10	18,03	84,05	18,28	84,00						
87	85,70	15,11	85,61	15,48	85,54	15,85	85,47	16,23	85,40	16,60	85,33	16,97	85,25	17,35	85,18	17,72	85,13	17,97	85,08	18,22	85,03	18,46	84,98						
88	86,68	15,28	86,60	15,66	86,53	16,04	86,46	16,41	86,38	16,79	86,31	17,17	86,23	17,55	86,16	17,92	86,11	18,17	86,06	18,40	86,01	18,63	85,96						
89	87,67	15,46	87,58	15,84	87,51	16,22	87,44	16,60	87,37	16,98	87,29	17,36	87,21	17,74	87,14	18,12	87,09	18,37	87,04	18,60	86,99	18,82	86,94						
90	88,65	15,62	88,56	16,02	88,49	16,40	88,42	16,79	88,35	17,17	88,27	17,56	88,19	17,94	88,12	18,33	88,07	18,58	88,02	18,84	87,97	19,06	87,92						
91	89,62	15,80	89,55	16,19	89,48	16,53	89,40	16,97	89,33	17,36	89,25	17,75	89,17	18,14	89,09	18,53	89,04	18,79	88,99	19,01	88,94	19,23	88,89						
92	90,60	15,98	90,53	16,37	90,46	16,77	90,39	17,16	90,31	17,56	90,23	17,95	90,15	18,34	90,07	18,74	90,02	18,99	89,97	19,21	89,92	19,43	89,87						
93	91,59	16,15	91,52	16,55	91,44	16,95	91,37	17,35	91,29	17,75	91,21	18,14	91,13	18,54	91,05	18,94	91,00	19,19	90,95	19,41	90,90	19,63	90,85						
94	92,57	16,32	92,50	16,73	92,43	17,13	92,35	17,53	92,27	17,94	92,19	18,34	92,11	18,74	92,03	19,14	92,00	19,25	91,95	19,47	91,90	19,69	91,85						
95	93,56	16,50	93,48	16,91	93,41	17,31	93,33	17,72	93,26	18,13	93,18	18,54	93,09	18,94	93,01	19,35	92,98	19,59	92,93	19,81	92,88	20,03	92,83						
96	94,54	16,67	94,47	17,08	94,39	17,50	94,32	17,91	94,24	18,32	94,16	18,73	94,07	19,14	93,99	19,55	93,96	19,76	93,91	20,01	93,86	20,23	93,81						
97	95,53	16,85	95,45	17,26	95,38	17,68	95,30	18,09	95,22	18,51	95,14	18,92	95,05	19,34	94,97	19,75	94,94	19,95	94,90	20,17	94,85	20,39	94,80						
98	96,51	17,02	96,44	17,44	96,36	17,86	96,28	18,28	96,20	18,70	96,12	19,12	96,03	19,54	95,95	19,96	95,90	20,15	95,85	20,35	95,80	20,55	95,75						
99	97,50	17,19	97,42	17,62	97,34	18,04	97,26	18,47	97,18	18,89	97,10	19,31	97,01	19,74	96,93	20,16	96,90	20,37	96,85	20,57	96,80	21,00	96,75						
100	98,48	17,37	98,40	17,79	98,33	18,22	98,25	18,65	98,16	19,08	98,08	19,51	97,99	19,94	97,91	20,36	97,86	20,55	97,81	20,99	97,76	21,42	97,71						
101	99,47	17,54	99,39	17,97	99,31	18,41	99,23	18,84	99,15	19,27	99,06	19,70	98,97	20,14	98,88	20,57	98,83	20,95	98,78	21,37	98,73	21,79	98,68						
102	100,4	17,71	100,4	18,15	100,3	18,59	100,2	19,03	100,1	19,46	100,0	19,90	99,95	20,34	99,8														

TRAVERSE TABLE, 67.

Distance	12 Degrees								13 Degrees								14 Degrees								Distance	
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.			
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
1	0,98	0,21	0,98	0,21	0,98	0,22	0,98	0,21	0,97	0,23	0,97	0,23	0,97	0,23	0,97	0,23	0,97	0,24	0,97	0,24	0,97	0,24	0,97	0,24	0,97	0,24
2	1,96	0,42	1,95	0,42	1,95	0,43	1,95	0,44	1,95	0,45	1,95	0,46	1,95	0,47	1,94	0,47	1,94	0,48	1,94	0,48	1,94	0,48	1,94	0,48	1,94	0,48
3	2,93	0,62	2,93	0,64	2,93	0,65	2,93	0,66	2,92	0,68	2,92	0,69	2,92	0,70	2,91	0,71	2,91	0,71	2,91	0,71	2,91	0,71	2,91	0,71	2,91	0,71
4	3,91	0,83	3,91	0,85	3,91	0,87	3,90	0,88	3,90	0,90	3,89	0,92	3,89	0,93	3,89	0,95	3,89	0,95	3,89	0,95	3,89	0,95	3,89	0,95	3,89	0,95
5	4,89	1,04	4,89	1,06	4,88	1,08	4,88	1,10	4,87	1,13	4,87	1,15	4,86	1,17	4,86	1,19	4,86	1,19	4,86	1,19	4,86	1,19	4,86	1,19	4,86	1,19
6	5,87	1,25	5,86	1,27	5,86	1,30	5,85	1,32	5,85	1,35	5,84	1,38	5,83	1,40	5,83	1,43	5,83	1,43	5,83	1,43	5,83	1,43	5,83	1,43	5,83	1,43
7	6,85	1,46	6,84	1,49	6,83	1,52	6,83	1,55	6,82	1,58	6,81	1,60	6,81	1,63	6,80	1,66	6,80	1,66	6,80	1,66	6,80	1,66	6,80	1,66	6,80	1,66
8	7,83	1,66	7,82	1,70	7,81	1,73	7,80	1,77	7,80	1,80	7,79	1,83	7,78	1,87	7,77	1,90	7,77	1,90	7,77	1,90	7,77	1,90	7,77	1,90	7,77	1,90
9	8,80	1,87	8,80	1,91	8,79	1,95	8,78	1,99	8,77	2,03	8,76	2,06	8,75	2,10	8,74	2,14	8,74	2,14	8,74	2,14	8,74	2,14	8,74	2,14	8,74	2,14
10	9,78	2,08	9,77	2,12	9,76	2,16	9,75	2,21	9,74	2,25	9,73	2,29	9,72	2,34	9,71	2,38	9,71	2,38	9,71	2,38	9,71	2,38	9,71	2,38	9,71	2,38
11	10,76	2,29	10,75	2,33	10,74	2,38	10,73	2,43	10,72	2,47	10,71	2,52	10,70	2,57	10,69	2,62	10,69	2,62	10,69	2,62	10,69	2,62	10,69	2,62	10,69	2,62
12	11,74	2,50	11,73	2,55	11,72	2,60	11,70	2,65	11,69	2,70	11,68	2,75	11,67	2,80	11,66	2,85	11,66	2,85	11,66	2,85	11,66	2,85	11,66	2,85	11,66	2,85
13	12,72	2,70	12,71	2,76	12,69	2,81	12,68	2,87	12,67	2,92	12,65	2,98	12,64	3,03	12,63	3,09	12,63	3,09	12,63	3,09	12,63	3,09	12,63	3,09	12,63	3,09
14	13,70	2,91	13,68	2,97	13,67	3,03	13,66	3,09	13,64	3,15	13,63	3,21	13,61	3,27	13,60	3,33	13,60	3,33	13,60	3,33	13,60	3,33	13,60	3,33	13,60	3,33
15	14,67	3,12	14,66	3,18	14,65	3,25	14,63	3,31	14,62	3,37	14,60	3,44	14,59	3,50	14,57	3,57	14,57	3,57	14,57	3,57	14,57	3,57	14,57	3,57	14,57	3,57
16	15,65	3,33	15,64	3,40	15,62	3,46	15,61	3,53	15,59	3,60	15,57	3,67	15,56	3,74	15,54	3,80	15,54	3,80	15,54	3,80	15,54	3,80	15,54	3,80	15,54	3,80
17	16,63	3,53	16,61	3,61	16,60	3,68	16,58	3,75	16,57	3,82	16,55	3,90	16,53	3,97	16,51	4,04	16,51	4,04	16,51	4,04	16,51	4,04	16,51	4,04	16,51	4,04
18	17,61	3,74	17,59	3,82	17,57	3,90	17,56	3,97	17,54	4,05	17,52	4,13	17,50	4,20	17,48	4,28	17,48	4,28	17,48	4,28	17,48	4,28	17,48	4,28	17,48	4,28
19	18,59	3,95	18,57	4,03	18,55	4,11	18,53	4,19	18,51	4,27	18,49	4,36	18,48	4,44	18,46	4,52	18,46	4,52	18,46	4,52	18,46	4,52	18,46	4,52	18,46	4,52
20	19,56	4,16	19,55	4,24	19,53	4,33	19,51	4,41	19,49	4,50	19,47	4,58	19,45	4,67	19,43	4,75	19,43	4,75	19,43	4,75	19,43	4,75	19,43	4,75	19,43	4,75
21	20,54	4,37	20,52	4,46	20,50	4,55	20,48	4,64	20,46	4,72	20,44	4,81	20,42	4,90	20,40	4,99	20,40	4,99	20,40	4,99	20,40	4,99	20,40	4,99	20,40	4,99
22	21,52	4,57	21,50	4,67	21,48	4,76	21,46	4,86	21,44	4,95	21,42	5,04	21,39	5,14	21,37	5,23	21,37	5,23	21,37	5,23	21,37	5,23	21,37	5,23	21,37	5,23
23	22,50	4,78	22,48	4,88	22,46	4,98	22,43	5,08	22,41	5,17	22,39	5,27	22,36	5,37	22,34	5,47	22,34	5,47	22,34	5,47	22,34	5,47	22,34	5,47	22,34	5,47
24	23,48	4,99	23,45	5,09	23,43	5,20	23,41	5,30	23,38	5,40	23,36	5,50	23,34	5,60	23,31	5,71	23,31	5,71	23,31	5,71	23,31	5,71	23,31	5,71	23,31	5,71
25	24,45	5,20	24,43	5,31	24,41	5,41	24,39	5,51	24,36	5,62	24,34	5,73	24,31	5,84	24,28	5,94	24,28	5,94	24,28	5,94	24,28	5,94	24,28	5,94	24,28	5,94
26	25,43	5,41	25,41	5,52	25,38	5,63	25,36	5,74	25,33	5,85	25,31	5,96	25,28	6,07	25,26	6,18	25,26	6,18	25,26	6,18	25,26	6,18	25,26	6,18	25,26	6,18
27	26,41	5,61	26,39	5,73	26,36	5,85	26,34	5,96	26,31	6,07	26,28	6,19	26,25	6,30	26,23	6,42	26,23	6,42	26,23	6,42	26,23	6,42	26,23	6,42	26,23	6,42
28	27,39	5,82	27,36	5,94	27,34	6,06	27,31	6,18	27,28	6,30	27,26	6,42	27,23	6,54	27,20	6,66	27,20	6,66	27,20	6,66	27,20	6,66	27,20	6,66	27,20	6,66
29	28,37	6,03	28,34	6,15	28,31	6,28	28,29	6,40	28,26	6,52	28,23	6,65	28,20	6,77	28,17	6,89	28,17	6,89	28,17	6,89	28,17	6,89	28,17	6,89	28,17	6,89
30	29,35	6,24	29,32	6,37	29,29	6,49	29,26	6,62	29,23	6,75	29,20	6,88	29,17	7,00	29,14	7,13	29,14	7,13	29,14	7,13	29,14	7,13	29,14	7,13	29,14	7,13
31	30,32	6,45	30,29	6,58	30,27	6,71	30,24	6,84	30,21	6,97	30,17	7,11	30,14	7,24	30,11	7,37	30,11	7,37	30,11	7,37	30,11	7,37	30,11	7,37	30,11	7,37
32	31,30	6,65	31,27	6,79	31,24	6,93	31,21	7,06	31,18	7,20	31,15	7,33	31,12	7,47	31,08	7,61	31,08	7,61	31,08	7,61	31,08	7,61	31,08	7,61	31,08	7,61
33	32,28	6,86	32,25	7,00	32,22	7,14	32,19	7,28	32,15	7,42	32,12	7,56	32,09	7,70	32,05	7,84	32,05	7,84	32,05	7,84	32,05	7,84	32,05	7,84	32,05	7,84
34	33,26	7,07	33,23	7,21	33,19	7,36	33,16	7,50	33,13	7,65	33,10	7,79	33,06	7,94	33,03	8,08	33,03	8,08	33,03	8,08	33,03	8,08	33,03	8,08	33,03	8,08
35	34,24	7,28	34,20	7,43	34,17	7,58	34,14	7,73	34,10	7,87	34,07	8,02	34,03	8,17	34,00	8,32	34,00	8,32	34,00	8,32	34,00	8,32	34,00	8,32	34,00	8,32
36	35,21	7,48	35,18	7,64	35,15	7,79	35,11	7,95	35,08	8,10	35,04	8,25	35,01	8,41	34,97	8,56	34,97	8,56	34,97	8,56	34,97	8,56	34,97	8,56	34,97	8,56
37	36,19	7,69	36,16	7,85	36,12	8,01	36,09	8,17	36,05	8,32	36,02	8,48	35,98	8,64	35,94	8,80	35,94	8,80	35,94	8,80	35,94	8,80	35,94	8,80	35,94	8,80
38	37,17	7,90	37,14	8,06	37,10	8,23	37,06	8,39	37,03	8,55	36,99	8,71	36,95	8,87	36,91	9,03	36,91	9,03	36,91	9,03	36,91	9,03	36,91	9,03	36,91	9,03
39	38,15	8,11	38,11	8,28	38,08	8,44	38,04	8,61	38,00	8,77	37,96	8,94	37,92	9,11	37,88	9,27	37,88	9,27	37,88	9,27	37,88	9,27	37,88	9,27	37,88	9,27
40	39,13	8,32	39,09	8,48	39,05	8,66	39,01	8,83	38,98	9,00	38,94	9,17	38,90	9,34	38,85	9,51	38,85	9,51	38,85	9,51	38,85	9,51	38,85	9,51	38,85	9,51
41	40,10	8,52	40,07	8,70	40,03	8,88	39,99	9,05	39,95	9,22	39,91	9,40	39,87	9,57	39,83	9,75	39,83	9,75	39,83	9,75	39,83	9,75	39,83	9,75	39,83	9,75
42	41,08	8,73	41,04	8,91	41,01	9,09	40,97	9,27	40,92	9,45	40,88	9,63	40,84	9,81	40,80	9,98	40,80	9,98	40,80	9,98	40,80	9,98	40,80	9,98	40,80	9,98
43	42,06	8,94	42,02	9,12	41,98	9,31	41,94	9,49	41,90	9,67	41,86	9,86	41,81	10,04	41,77	10,22	41,77	10,22	41,77	10,22	41,77	10,22	41,77	10,22	41,77	10,22
44	43,04	9,15	43,00	9,34	42,96	9,52	42,92	9,71	42,87	9,90	42,83	10,09	42,78	10,27	42,74	10,46	42,74	10,46	42,74	10,46	42,74	10,46	42,74	10,46	42,74	10,46
45	44,02	9,36	43,98	9,55	43,93	9,74	43,89	9,93	43,85	10,12	43,80	10,31	43,76	10,51	43,71	10,70	43,71	10,70	43,71	10,70	43,71	10,70	43,71	10,70	43,71	10,70
46	45,00	9,56	44,95	9,76	44,91	9,96	44,87	10,15	44,82	10,35	44,78	10,54	44,73	10,74	44,68	10,93	44,68	10,93	44,68	10,93	44,68	10,93	44,68	10,93	44,68	10,93
47	45,97	9,77	45,93	9,97	45,89	10,17	45,84	10,37	45,80	10,57	45,75	10,77	45,70	10,97	45,65	11,17	45,65	11,17	45,65	11,17	45,65	11,17	45,65	11,17	45,65	11,17
48	46,																									

TRAVERSE TABLE, 67.

99

12 Degrees																13 Degrees																14 Degrees																Distance
,21																,23																,25																
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.																		
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.																	
61	59,6	12,68	59,61	12,94	59,55	13,20	59,50	13,46	59,44	13,72	59,38	13,98	59,31	14,24	59,25	14,50	59,18	14,76	59,11	15,02	59,04	15,28	58,97	15,54	58,90	15,80	58,83	16,06	58,76	16,32	61																	
62	60,6	12,89	60,59	13,16	60,53	13,42	60,47	13,68	60,41	13,95	60,35	14,21	60,29	14,47	60,22	14,74	60,15	15,00	60,08	15,26	60,01	15,52	59,94	15,78	59,87	16,04	59,80	16,30	59,73	16,56	62																	
63	61,6	13,10	61,57	13,37	61,51	13,64	61,45	13,90	61,38	14,17	61,32	14,44	61,26	14,71	61,19	14,97	61,12	15,23	61,05	15,49	60,98	15,75	60,91	16,01	60,84	16,27	60,77	16,53	60,70	16,79	63																	
64	62,6	13,31	62,54	13,58	62,48	13,85	62,42	14,13	62,36	14,40	62,30	14,67	62,23	14,93	62,17	15,21	62,10	15,47	62,03	15,73	61,96	15,99	61,89	16,25	61,82	16,51	61,75	16,77	61,68	17,03	64																	
65	63,5	13,52	63,52	13,79	63,46	14,07	63,40	14,35	63,33	14,61	63,27	14,90	63,20	15,17	63,14	15,45	63,07	15,71	63,00	15,97	62,93	16,23	62,86	16,49	62,79	16,75	62,72	17,01	62,65	17,27	65																	
66	64,5	13,72	64,50	14,00	64,44	14,29	64,37	14,57	64,31	14,85	64,24	15,13	64,18	15,41	64,11	15,69	64,04	15,95	63,97	16,21	63,90	16,47	63,83	16,73	63,76	17,00	63,69	17,26	63,62	17,52	66																	
67	65,5	13,93	65,48	14,21	65,41	14,50	65,35	14,79	65,28	15,07	65,22	15,36	65,15	15,64	65,08	15,93	65,01	16,19	64,94	16,45	64,87	16,71	64,80	16,97	64,73	17,23	64,66	17,49	64,59	17,75	67																	
68	66,5	14,14	66,45	14,43	66,39	14,72	66,32	15,01	66,26	15,30	66,19	15,59	66,12	15,88	66,05	16,16	65,98	16,43	65,91	16,69	65,84	16,95	65,77	17,21	65,70	17,47	65,63	17,73	65,56	17,99	68																	
69	67,4	14,35	67,43	14,64	67,37	14,93	67,30	15,23	67,23	15,52	67,16	15,82	67,09	16,11	67,02	16,40	66,95	16,66	66,88	16,92	66,81	17,18	66,74	17,44	66,67	17,70	66,60	17,96	66,53	18,22	69																	
70	68,4	14,55	68,41	14,85	68,34	15,15	68,27	15,45	68,21	15,75	68,14	16,04	68,07	16,34	67,99	16,61	67,92	16,87	67,84	17,13	67,77	17,39	67,70	17,65	67,63	17,91	67,56	18,17	67,49	18,43	70																	
71	69,4	14,76	69,38	15,07	69,32	15,37	69,25	15,67	69,18	15,97	69,11	16,27	69,04	16,58	68,97	16,88	68,90	17,15	68,83	17,41	68,76	17,67	68,69	17,93	68,62	18,19	68,55	18,45	68,48	18,71	71																	
72	70,4	14,97	70,36	15,28	70,29	15,58	70,23	15,89	70,15	16,20	70,08	16,50	70,01	16,81	69,94	17,11	69,87	17,38	69,80	17,66	69,73	17,92	69,66	18,18	69,59	18,44	69,52	18,70	69,45	18,96	72																	
73	71,4	15,18	71,34	15,49	71,27	15,80	71,20	16,11	71,13	16,42	71,06	16,73	70,98	17,04	70,91	17,33	70,84	17,60	70,77	17,86	70,70	18,12	70,63	18,38	70,56	18,64	70,49	18,90	70,42	19,16	73																	
74	72,3	15,39	72,32	15,70	72,25	16,02	72,18	16,33	72,10	16,65	72,03	16,96	71,96	17,28	71,88	17,59	71,81	17,85	71,74	18,11	71,67	18,37	71,60	18,63	71,53	18,89	71,46	19,14	71,39	19,40	74																	
75	73,3	15,59	73,29	15,91	73,22	16,23	73,15	16,55	73,08	16,87	73,00	17,19	72,93	17,51	72,85	17,82	72,78	18,08	72,71	18,34	72,64	18,54	72,57	18,84	72,50	19,10	72,43	19,38	72,36	19,64	75																	
76	74,3	15,80	74,27	16,13	74,20	16,45	74,13	16,77	74,05	17,10	73,98	17,42	73,90	17,74	73,82	18,06	73,75	18,31	73,68	18,58	73,61	18,84	73,54	19,10	73,47	19,36	73,40	19,62	73,33	19,88	76																	
77	75,2	16,01	75,25	16,34	75,18	16,67	75,10	16,99	75,03	17,32	74,95	17,65	74,87	17,98	74,80	18,24	74,73	18,49	74,66	18,75	74,59	19,01	74,52	19,27	74,45	19,53	74,38	19,79	74,31	20,05	77																	
78	76,2	16,22	76,22	16,55	76,16	16,88	76,08	17,22	76,00	17,55	75,92	17,88	75,85	18,21	75,77	18,54	75,70	18,80	75,63	19,07	75,56	19,32	75,49	19,58	75,42	19,84	75,35	20,10	75,28	20,36	78																	
79	77,2	16,43	77,20	16,76	77,13	17,10	77,05	17,44	76,97	17,77	76,90	18,11	76,82	18,44	76,74	18,78	76,67	19,04	76,60	19,30	76,53	19,56	76,46	19,81	76,39	20,07	76,32	20,32	76,25	20,58	79																	
80	78,2	16,63	78,18	16,97	78,10	17,32	78,03	17,66	77,95	18,00	77,87	18,34	77,79	18,68	77,71	19,02	77,64	19,28	77,57	19,53	77,50	19,78	77,43	20,03	77,36	20,29	77,29	20,54	77,22	20,80	80																	
81	79,2	16,84	79,16	17,19	79,08	17,53	79,00	17,88	78,92	18,22	78,84	18,57	78,76	18,91	78,68	19,25	78,61	19,50	78,54	19,76	78,47	20,01	78,40	20,26	78,33	20,51	78,26	20,76	78,19	21,02	81																	
82	80,2	17,05	80,13	17,40	80,06	17,75	79,98	18,10	79,90	18,45	79,82	18,79	79,74	19,14	79,66	19,49	79,59	19,75	79,52	20,00	79,45	20,25	79,38	20,50	79,31	20,73	79,24	20,98	79,17	21,24	82																	
83	81,1	17,26	81,11	17,61	81,03	17,97	80,95	18,32	80,87	18,67	80,79	19,02	80,71	19,38	80,62	19,73	80,55	20,00	80,47	20,27	80,40	20,48	80,33	20,70	80,26	20,94	80,19	21,19	80,12	21,45	83																	
84	82,1	17,47	82,09	17,82	82,01	18,18	81,93	18,54	81,85	18,90	81,76	19,25	81,68	19,61	81,59	19,97	81,52	20,20	81,45	20,44	81,38	20,68	81,31	20,92	81,24	21,15	81,17	21,40	81,10	21,72	84																	
85	83,1	17,67	83,06	18,04	82,99	18,40	82,91	18,76	82,82	19,12	82,74	19,48	82,66	19,84	82,59	20,10	82,52	20,36	82,45	20,60	82,38	20,84	82,31	21,05	82,24	21,27	82,17	21,50	82,10	21,82	85																	
86	84,1	17,88	84,04	18,25	83,96	18,61	83,88	18,98	83,80	19,35	83,71	19,71	83,62	20,08	83,54	20,44	83,47	20,68	83,40	20,92	83,33	21,15	83,26	21,39	83,19	21,62	83,12	21,85	83,05	22,17	86																	
87	85,1	18,09	85,02	18,46	84,94	18,83	84,86	19,20	84,77	19,57	84,68	19,94	84,60	20,31	84,51	20,68	84,44	20,92	84,37	21,15	84,30	21,38	84,23	21,61	84,16	21,84	84,09	22,07	84,02	22,39	87																	
88	86,0	18,30	86,00	18,67	85,92	19,05	85,83	19,42	85,74	19,80	85,66	20,17	85,57	20,54	85,48	20,92	85,41	21,15	85,34	21,38	85,27	21,61	85,20	21,84	85,13	22,07	85,06	22,30	85,00	22,62	88																	
89	87,0	18,50	86,97	18,84	86,89	19,26	86,81	19,64	86,72	20,02	86,63	20,40	86,54	20,76	86,45	21,15	86,38	21,38	86,31	21,61	86,24	21,84	86,17	22,07	86,10	22,30	86,03	22,53	85,96	22,85	89																	
90	88,0	18,71	87,95	19,10	87,87	19,48	87,78	19,86	87,69	20,25	87,60	20,63	87,51	21,01	87,42	21,30	87,35	21,54	87,28	21,78	87,21	22,01	87,14	22,24	87,07	22,47	87,00	22,70	86,93	23,02	90																	
91	89,0	18,92	88,93	19,31	88,84	19,70	88,76	20,08	88,67	20,47	88,58	20,86	88,49	21,24	88,41	21,63	88,34	21,87	88,27	22,07	88,20	22,27	88,13	22,47	88,06	22,67	87,99	22,87	87,92	23,17	91																	
92	89,9	19,13	89,91	19,52	89,82	19,91	89,73	20,30	89,64	20,69	89,55	21,08	89,46	21,48	89,38	21,87	89,31	22,07	89,24	22,27	89,17	22,47	89,10	22,67	8																							

TRAVERSE TABLE, 67.

Distance	14 Degrees								,25	15 Degrees								,2	Distance																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
	0 Min.		15 Min.		30 Min.		45 Min.			0 Min.		15 Min.		30 Min.		45 Min.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
1	0,97	0,24	0,97	0,25	0,97	0,25	0,97	0,25	0,97	0,26	0,96	0,26	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0,96	0,27	0

Distance	16 Degrees								29	17 Degrees								31	Distance
	0 Min.		15 Min.		30 Min.		45 Min.			0 Min.		15 Min.		30 Min.		45 Min.			
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
1	0,96	0,28	0,96	0,28	0,96	0,28	0,96	0,29	0,96	0,29	0,96	0,30	0,95	0,30	0,95	0,31	1		
2	1,92	0,55	1,92	0,56	1,92	0,57	1,92	0,58	1,91	0,59	1,91	0,59	1,91	0,60	1,91	0,61	2		
3	2,88	0,83	2,88	0,84	2,88	0,85	2,87	0,87	2,87	0,88	2,87	0,89	2,86	0,90	2,86	0,92	3		
4	3,84	1,10	3,84	1,12	3,84	1,14	3,83	1,15	3,82	1,17	3,82	1,19	3,82	1,20	3,81	1,22	4		
5	4,80	1,38	4,80	1,40	4,79	1,42	4,79	1,44	4,78	1,46	4,78	1,48	4,77	1,50	4,76	1,52	5		
6	5,77	1,65	5,76	1,68	5,75	1,70	5,75	1,73	5,74	1,75	5,73	1,78	5,72	1,80	5,71	1,83	6		
7	6,73	1,93	6,72	1,96	6,71	1,99	6,70	2,02	6,69	2,05	6,69	2,08	6,68	2,11	6,67	2,13	7		
8	7,69	2,21	7,68	2,24	7,67	2,27	7,66	2,31	7,65	2,34	7,64	2,37	7,63	2,41	7,62	2,44	8		
9	8,65	2,48	8,64	2,52	8,63	2,56	8,62	2,59	8,61	2,63	8,60	2,67	8,58	2,71	8,57	2,74	9		
10	9,61	2,76	9,60	2,80	9,59	2,84	9,58	2,86	9,56	2,92	9,55	2,97	9,54	3,01	9,52	3,05	10		
11	10,57	3,03	10,56	3,08	10,55	3,12	10,53	3,17	10,52	3,22	10,51	3,26	10,49	3,31	10,48	3,35	11		
12	11,54	3,31	11,52	3,36	11,51	3,41	11,49	3,46	11,48	3,51	11,46	3,56	11,45	3,61	11,43	3,66	12		
13	12,50	3,58	12,48	3,64	12,46	3,69	12,45	3,75	12,43	3,81	12,42	3,86	12,40	3,91	12,38	3,96	13		
14	13,46	3,86	13,44	3,92	13,42	3,98	13,41	4,04	13,39	4,09	13,37	4,15	13,35	4,21	13,33	4,27	14		
15	14,42	4,13	14,40	4,20	14,38	4,26	14,36	4,33	14,35	4,39	14,33	4,45	14,31	4,51	14,29	4,57	15		
16	15,38	4,41	15,36	4,48	15,34	4,54	15,32	4,61	15,30	4,68	15,28	4,74	15,26	4,81	15,24	4,88	16		
17	16,34	4,69	16,32	4,76	16,30	4,83	16,28	4,90	16,26	4,97	16,24	5,04	16,21	5,11	16,19	5,18	17		
18	17,30	4,96	17,28	5,04	17,26	5,11	17,23	5,19	17,21	5,26	17,19	5,34	17,17	5,41	17,14	5,49	18		
19	18,26	5,24	18,24	5,32	18,22	5,40	18,19	5,48	18,17	5,56	18,15	5,63	18,12	5,71	18,10	5,79	19		
20	19,23	5,51	19,20	5,60	19,18	5,68	19,15	5,76	19,13	5,85	19,10	5,93	19,07	6,01	19,05	6,10	20		
21	20,19	5,79	20,16	5,88	20,14	5,96	20,11	6,05	20,08	6,14	20,06	6,23	20,03	6,31	20,00	6,40	21		
22	21,15	6,06	21,12	6,16	21,09	6,25	21,07	6,34	21,04	6,43	21,01	6,52	20,98	6,62	20,95	6,71	22		
23	22,11	6,34	22,08	6,44	22,05	6,53	22,02	6,63	22,00	6,72	21,97	6,82	21,94	6,92	21,91	7,01	23		
24	23,07	6,62	23,04	6,72	23,01	6,82	22,98	6,92	22,95	7,02	22,92	7,12	22,89	7,22	22,86	7,32	24		
25	24,03	6,89	24,00	7,00	23,97	7,10	23,94	7,21	23,91	7,31	23,88	7,41	23,84	7,52	23,81	7,62	25		
26	24,99	7,17	24,96	7,28	24,93	7,38	24,90	7,49	24,86	7,60	24,83	7,71	24,80	7,82	24,76	7,93	26		
27	25,95	7,44	25,92	7,56	25,89	7,67	25,85	7,78	25,82	7,89	25,79	8,01	25,75	8,12	25,72	8,23	27		
28	26,91	7,72	26,88	7,84	26,85	7,95	26,81	8,07	26,78	8,19	26,74	8,30	26,70	8,42	26,67	8,54	28		
29	27,88	7,99	27,84	8,12	27,81	8,24	27,77	8,36	27,73	8,48	27,70	8,60	27,66	8,72	27,62	8,84	29		
30	28,84	8,27	28,80	8,40	28,77	8,52	28,73	8,65	28,69	8,77	28,65	8,90	28,61	9,02	28,57	9,15	30		
31	29,80	8,55	29,76	8,68	29,72	8,81	29,68	8,93	29,65	9,06	29,61	9,19	29,57	9,32	29,52	9,45	31		
32	30,76	8,82	30,72	8,96	30,69	9,09	30,64	9,22	30,60	9,36	30,56	9,49	30,52	9,62	30,48	9,76	32		
33	31,72	9,10	31,68	9,23	31,64	9,37	31,60	9,51	31,56	9,65	31,52	9,79	31,47	9,92	31,43	10,06	33		
34	32,68	9,37	32,64	9,51	32,60	9,66	32,56	9,80	32,51	9,94	32,47	10,08	32,42	10,22	32,38	10,37	34		
35	33,64	9,65	33,60	9,79	33,56	9,94	33,51	10,09	33,47	10,23	33,43	10,38	33,38	10,53	33,33	10,67	35		
36	34,61	9,92	34,56	10,07	34,52	10,23	34,47	10,38	34,43	10,53	34,38	10,68	34,33	10,83	34,29	10,97	36		
37	35,57	10,20	35,52	10,35	35,48	10,51	35,43	10,66	35,39	10,82	35,34	10,97	35,29	11,13	35,24	11,28	37		
38	36,53	10,47	36,48	10,63	36,44	10,79	36,39	10,95	36,34	11,11	36,29	11,27	36,24	11,43	36,19	11,58	38		
39	37,49	10,75	37,44	10,91	37,39	11,08	37,35	11,24	37,30	11,40	37,25	11,56	37,20	11,73	37,14	11,89	39		
40	38,45	11,03	38,40	11,19	38,35	11,36	38,30	11,53	38,25	11,70	38,20	11,86	38,15	12,03	38,10	12,19	40		
41	39,41	11,30	39,36	11,47	39,31	11,65	39,26	11,82	39,21	11,99	39,16	12,16	39,10	12,33	39,05	12,50	41		
42	40,37	11,58	40,32	11,75	40,27	11,93	40,22	12,10	40,17	12,28	40,11	12,46	40,06	12,63	40,00	12,80	42		
43	41,33	11,85	41,28	12,03	41,23	12,21	41,18	12,40	41,12	12,57	41,07	12,75	41,01	12,93	40,95	13,11	43		
44	42,30	12,13	42,24	12,31	42,19	12,50	42,13	12,68	42,08	12,86	42,02	13,05	41,96	13,23	41,91	13,41	44		
45	43,26	12,40	43,20	12,59	43,15	12,78	43,09	12,97	43,03	13,15	42,98	13,34	42,92	13,53	42,86	13,72	45		
46	44,22	12,68	44,16	12,87	44,11	13,07	44,05	13,26	43,99	13,45	43,93	13,64	43,87	13,83	43,81	14,02	46		
47	45,18	12,96	45,12	13,15	45,07	13,35	45,01	13,55	44,95	13,74	44,89	13,94	44,83	14,13	44,76	14,33	47		
48	46,14	13,23	46,08	13,43	46,02	13,63	45,96	13,83	45,90	14,03	45,84	14,23	45,78	14,43	45,72	14,63	48		
49	47,10	13,51	47,04	13,71	46,98	13,92	46,92	14,12	46,86	14,33	46,80	14,53	46,73	14,74	46,67	14,94	49		
50	48,06	13,78	48,00	13,99	47,94	14,20	47,88	14,41	47,82	14,62	47,75	14,83	47,69	15,04	47,62	15,24	50		
51	49,02	14,06	48,96	14,27	48,90	14,49	48,84	14,70	48,77	14,91	48,71	15,12	48,64	15,34	48,57	15,55	51		
52	49,99	14,33	49,92	14,55	49,86	14,78	49,79	14,98	49,73	15,20	49,66	15,42	49,59	15,64	49,53	15,85	52		
53	50,95	14,61	50,88	14,83	50,82	15,05	50,75	15,28	50,68	15,50	50,62	15,72	50,55	15,94	50,48	16,16	53		
54	51,91	14,89	51,84	15,11	51,78	15,34	51,71	15,56	51,64	15,79	51,57	16,01	51,50	16,24	51,43	16,46	54		
55	52,87	15,16	52,80	15,39	52,74	15,62	52,67	15,85	52,60	16,08	52,53	16,31	52,46	16,54	52,38	16,77	55		
56	53,83	15,44	53,76	15,67	53,69	15,91	53,62	16,14	53,55	16,37	53,48	16,61	53,41	16,84	53,34	17,07	56		
57	54,79	15,71	54,72	15,95	54,65	16,19	54,58	16,43	54,51	16,67	54,44	16,90	54,36	17,14	54,29	17,38	57		
58	55,75	15,99	55,68	16,23	55,61	16,47	55,54	16,72	55,47	16,96	55,39	17,20	55,32	17,44	55,24	17,68	58		
59	56,71	16,26	56,64	16,51	56,57	16,76	56,50	17,00	56,42	17,25	56,35	17,50	56,27	17,74	56,19	17,99	59		
60	57,68	16,54	57,60	16,79	57,53	17,04	57,45	17,29	57,38	17,54	57,30	17,79	57,22	18,04	57,14	18,30	60		
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance		
	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.				
	74 Deg.				73 Degrees				3,3				72 Degrees				3,1		

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[illegible]

Distance	18 Degrees								Distance	19 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.			0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0,95	0,31	0,95	0,31	0,95	0,32	0,95	0,32	0,95	0,33	0,94	0,33	0,94	0,33	0,94	0,34	1	
2	1,90	0,62	1,90	0,63	1,90	0,63	1,89	0,64	1,89	0,65	1,89	0,66	1,88	0,67	1,88	0,68	2	
3	2,85	0,93	2,85	0,94	2,84	0,95	2,84	0,96	2,84	0,98	2,83	0,99	2,83	1,00	2,82	1,01	3	
4	3,80	1,24	3,80	1,25	3,79	1,27	3,79	1,29	3,78	1,30	3,78	1,32	3,77	1,33	3,76	1,35	4	
5	4,75	1,54	4,75	1,57	4,74	1,59	4,73	1,61	4,73	1,63	4,72	1,65	4,71	1,67	4,71	1,69	5	
6	5,71	1,85	5,70	1,88	5,69	1,90	5,68	1,93	5,67	1,95	5,66	1,98	5,66	2,00	5,65	2,03	6	
7	6,66	2,16	6,65	2,19	6,64	2,22	6,63	2,25	6,62	2,28	6,61	2,31	6,60	2,34	6,59	2,36	7	
8	7,61	2,47	7,60	2,50	7,59	2,54	7,57	2,57	7,56	2,60	7,55	2,64	7,54	2,67	7,53	2,70	8	
9	8,56	2,78	8,55	2,82	8,53	2,86	8,52	2,89	8,51	2,93	8,50	2,97	8,48	3,00	8,47	3,04	9	
10	9,51	3,09	9,50	3,13	9,48	3,17	9,47	3,21	9,46	3,26	9,44	3,30	9,43	3,34	9,41	3,38	10	
11	10,46	3,40	10,45	3,44	10,43	3,49	10,42	3,54	10,40	3,58	10,38	3,63	10,37	3,67	10,35	3,72	11	
12	11,41	3,71	11,40	3,76	11,38	3,81	11,36	3,86	11,35	3,91	11,33	3,96	11,31	4,01	11,29	4,06	12	
13	12,36	4,02	12,35	4,07	12,33	4,12	12,31	4,18	12,29	4,23	12,27	4,29	12,25	4,34	12,24	4,39	13	
14	13,31	4,33	13,30	4,38	13,28	4,44	13,26	4,50	13,24	4,56	13,22	4,62	13,20	4,67	13,18	4,73	14	
15	14,27	4,63	14,24	4,70	14,22	4,76	14,20	4,82	14,18	4,88	14,16	4,95	14,14	5,01	14,12	5,07	15	
16	15,22	4,94	15,19	5,01	15,17	5,08	15,15	5,14	15,13	5,21	15,11	5,27	15,08	5,34	15,06	5,41	16	
17	16,17	5,25	16,14	5,32	16,12	5,39	16,10	5,46	16,07	5,53	16,05	5,60	16,02	5,67	16,00	5,74	17	
18	17,12	5,56	17,09	5,64	17,07	5,71	17,04	5,79	17,02	5,86	16,99	5,93	16,97	6,01	16,94	6,08	18	
19	18,07	5,87	18,04	5,95	18,02	6,03	17,99	6,11	17,97	6,19	17,94	6,26	17,91	6,34	17,88	6,42	19	
20	19,02	6,18	18,99	6,26	18,97	6,35	18,94	6,43	18,91	6,51	18,88	6,59	18,85	6,68	18,82	6,76	20	
21	19,97	6,49	19,94	6,58	19,91	6,66	19,89	6,75	19,86	6,84	19,83	6,92	19,80	7,01	19,76	7,10	21	
22	20,92	6,80	20,89	6,89	20,86	6,98	20,83	7,07	20,80	7,16	20,77	7,25	20,74	7,34	20,71	7,43	22	
23	21,87	7,11	21,84	7,20	21,81	7,30	21,78	7,39	21,75	7,49	21,71	7,58	21,68	7,68	21,65	7,77	23	
24	22,82	7,42	22,79	7,52	22,76	7,61	22,73	7,71	22,69	7,81	22,66	7,91	22,62	8,01	22,59	8,11	24	
25	23,78	7,72	23,74	7,83	23,71	7,93	23,67	8,04	23,64	8,14	23,60	8,24	23,57	8,34	23,53	8,45	25	
26	24,73	8,03	24,69	8,14	24,66	8,25	24,62	8,36	24,58	8,46	24,55	8,57	24,51	8,68	24,47	8,79	26	
27	25,68	8,34	25,64	8,45	25,60	8,57	25,57	8,68	25,53	8,79	25,49	8,90	25,45	9,01	25,41	9,12	27	
28	26,63	8,65	26,59	8,77	26,55	8,88	26,51	9,00	26,47	9,12	26,43	9,23	26,39	9,35	26,35	9,46	28	
29	27,58	8,96	27,54	9,08	27,50	9,20	27,46	9,32	27,42	9,44	27,38	9,56	27,34	9,68	27,29	9,80	29	
30	28,53	9,27	28,49	9,39	28,45	9,52	28,41	9,64	28,37	9,77	28,32	9,89	28,28	10,01	28,23	10,14	30	
31	29,48	9,58	29,44	9,71	29,40	9,84	29,35	9,96	29,31	10,09	29,27	10,22	29,22	10,35	29,18	10,48	31	
32	30,43	9,89	30,39	10,02	30,35	10,15	30,30	10,29	30,26	10,42	30,21	10,55	30,16	10,68	30,12	10,81	32	
33	31,38	10,20	31,34	10,33	31,29	10,47	31,25	10,61	31,20	10,74	31,15	10,88	31,11	11,01	31,06	11,15	33	
34	32,34	10,51	32,30	10,65	32,24	10,79	32,19	10,93	32,15	11,07	32,10	11,21	32,05	11,35	32,00	11,49	34	
35	33,29	10,82	33,25	10,96	33,19	11,11	33,14	11,25	33,09	11,39	33,04	11,54	32,99	11,68	32,94	11,83	35	
36	34,24	11,12	34,20	11,27	34,14	11,42	34,09	11,57	34,04	11,72	33,99	11,87	33,93	12,02	33,88	12,17	36	
37	35,19	11,43	35,15	11,59	35,09	11,74	35,04	11,89	34,98	12,05	34,93	12,20	34,88	12,35	34,82	12,50	37	
38	36,14	11,74	36,10	11,90	36,04	12,06	35,98	12,21	35,93	12,37	35,88	12,53	35,82	12,68	35,76	12,84	38	
39	37,09	12,05	37,05	12,21	36,98	12,37	36,93	12,54	36,88	12,70	36,82	12,86	36,76	13,02	36,71	13,18	39	
40	38,04	12,36	37,99	12,53	37,93	12,69	37,88	12,86	37,82	13,02	37,76	13,19	37,71	13,35	37,65	13,52	40	
41	38,99	12,67	38,94	12,84	38,88	13,01	38,81	13,18	38,77	13,34	38,71	13,52	38,65	13,69	38,59	13,85	41	
42	39,94	12,98	39,89	13,15	39,83	13,33	39,77	13,50	39,71	13,67	39,65	13,85	39,59	14,02	39,53	14,19	42	
43	40,89	13,29	40,84	13,46	40,78	13,64	40,72	13,82	40,66	14,00	40,60	14,18	40,53	14,35	40,47	14,53	43	
44	41,85	13,60	41,79	13,78	41,73	13,96	41,66	14,14	41,60	14,32	41,54	14,51	41,48	14,69	41,41	14,87	44	
45	42,80	13,91	42,74	14,09	42,67	14,28	42,61	14,47	42,55	14,65	42,48	14,84	42,42	15,02	42,35	15,21	45	
46	43,75	14,21	43,69	14,40	43,62	14,60	43,56	14,79	43,49	14,98	43,43	15,17	43,36	15,35	43,29	15,54	46	
47	44,70	14,52	44,63	14,72	44,57	14,91	44,51	15,11	44,44	15,30	44,37	15,50	44,30	15,69	44,23	15,88	47	
48	45,65	14,83	45,58	15,03	45,52	15,23	45,45	15,43	45,39	15,63	45,32	15,82	45,25	16,02	45,18	16,22	48	
49	46,60	15,14	46,53	15,34	46,47	15,55	46,40	15,75	46,33	15,95	46,26	16,15	46,19	16,36	46,12	16,56	49	
50	47,55	15,45	47,48	15,66	47,42	15,86	47,35	16,07	47,28	16,28	47,21	16,48	47,13	16,69	47,06	16,90	50	
51	48,50	15,76	48,43	15,97	48,36	16,18	48,29	16,39	48,22	16,60	48,15	16,81	48,07	17,02	48,00	17,23	51	
52	49,45	16,07	49,38	16,28	49,31	16,50	49,24	16,71	49,17	16,93	49,09	17,14	49,02	17,36	48,94	17,57	52	
53	50,41	16,38	50,33	16,60	50,26	16,82	50,19	17,04	50,11	17,25	50,04	17,47	49,96	17,69	49,88	17,91	53	
54	51,36	16,69	51,28	16,91	51,21	17,13	51,13	17,36	51,06	17,58	50,98	17,80	50,90	18,03	50,82	18,25	54	
55	52,31	17,00	52,23	17,22	52,16	17,45	52,08	17,68	52,00	17,91	51,92	18,13	51,84	18,36	51,76	18,59	55	
56	53,26	17,30	53,18	17,54	53,11	17,77	53,03	18,00	52,95	18,23	52,87	18,46	52,79	18,69	52,71	18,92	56	
57	54,21	17,61	54,13	17,85	54,05	18,08	53,98	18,32	53,89	18,56	53,81	18,79	53,73	19,03	53,65	19,26	57	
58	55,16	17,92	55,08	18,16	55,00	18,40	54,92	18,64	54,84	18,88	54,76	19,12	54,67	19,36	54,59	19,60	58	
59	56,11	18,23	56,03	18,48	55,95	18,72	55,87	18,96	55,79	19,21	55,70	19,45	55,62	19,69	55,53	19,94	59	
60	57,06	18,54	56,98	18,79	56,90	19,04	56,82	19,29	56,73	19,53	56,64	19,78	56,56	20,03	56,47	20,27	60	
Distance	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.		Distance	
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.		
	72 Deg.		71 Degrees		2,9		70 Degrees		2,7									

TRAVERSE TABLE, 67.

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18 Degrees									32		19 Degrees									34	
0 Min.		15 Min.		30 Min.		45 Min.		Distance	0 Min.		15 Min.		30 Min.		45 Min.		Distance				
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.					
61	58,01	18,85	57,94	19,10	57,85	19,35	57,76	19,61	57,68	19,86	57,59	20,11	57,50	20,36	57,41	20,61	61				
62	58,07	19,16	58,89	19,42	58,80	19,67	58,71	19,93	58,62	20,18	58,53	20,44	58,44	20,70	58,35	20,95	62				
63	59,02	19,47	59,84	19,73	59,74	19,99	59,66	20,25	59,57	20,51	59,48	20,77	59,39	21,03	59,29	21,29	63				
64	60,07	19,78	60,79	20,04	60,69	20,31	60,60	20,57	60,51	20,84	60,42	21,10	60,33	21,36	60,24	21,63	64				
65	61,02	20,09	61,74	20,36	61,64	20,62	61,55	20,89	61,46	21,16	61,36	21,43	61,27	21,70	61,18	21,96	65				
66	62,07	20,39	62,69	20,67	62,59	20,94	62,50	21,21	62,40	21,49	62,31	21,76	62,21	22,03	62,12	22,30	66				
67	63,02	20,70	63,64	20,98	63,54	21,26	63,44	21,54	63,35	21,81	63,25	22,09	63,16	22,37	63,06	22,64	67				
68	64,07	21,01	64,59	21,29	64,49	21,58	64,39	21,86	64,29	22,14	64,20	22,42	64,10	22,70	64,00	22,98	68				
69	65,02	21,32	65,54	21,61	65,43	21,89	65,34	22,18	65,24	22,46	65,14	22,75	65,04	23,03	64,94	23,32	69				
70	66,07	21,63	66,48	21,92	66,38	22,21	66,28	22,50	66,19	22,79	66,07	23,08	65,98	23,37	65,88	23,65	70				
71	67,02	21,94	67,43	22,23	67,33	22,53	67,23	22,82	67,13	23,11	67,03	23,41	66,93	23,70	66,82	23,99	71				
72	68,07	22,25	68,38	22,55	68,28	22,85	68,18	23,14	68,07	23,44	67,97	23,74	67,87	24,03	67,76	24,33	72				
73	69,02	22,56	69,33	22,86	69,23	23,16	69,13	23,47	69,02	23,76	68,92	24,07	68,81	24,37	68,71	24,67	73				
74	70,07	22,87	70,28	23,17	70,18	23,48	70,07	23,79	69,97	24,09	69,86	24,40	69,76	24,70	69,65	25,01	74				
75	71,02	23,18	71,23	23,49	71,12	23,80	71,02	24,11	70,91	24,42	70,81	24,73	70,70	25,04	70,59	25,34	75				
76	72,07	23,48	72,18	23,80	72,07	24,11	71,97	24,43	71,86	24,74	71,75	25,06	71,64	25,37	71,53	25,68	76				
77	73,02	23,79	73,13	24,11	73,02	24,43	72,91	24,75	72,80	25,07	72,69	25,39	72,58	25,70	72,47	26,02	77				
78	74,07	24,10	74,08	24,43	73,97	24,75	73,86	25,07	73,75	25,39	73,64	25,72	73,53	26,04	73,41	26,36	78				
79	75,02	24,41	75,03	24,74	74,92	25,07	74,81	25,39	74,69	25,72	74,58	26,05	74,47	26,37	74,35	26,70	79				
80	76,07	24,72	75,98	25,05	75,87	25,38	75,75	25,71	75,64	26,04	75,53	26,37	75,41	26,70	75,29	27,03	80				
81	77,02	25,03	76,92	25,37	76,81	25,70	76,70	26,04	76,59	26,37	76,47	26,70	76,35	27,04	76,23	27,37	81				
82	78,07	25,34	77,87	25,68	77,76	26,02	77,65	26,36	77,53	26,70	77,41	27,03	77,30	27,37	77,18	27,71	82				
83	79,02	25,65	78,82	25,99	78,71	26,34	78,59	26,68	78,48	27,02	78,36	27,36	78,24	27,71	78,12	28,05	83				
84	80,07	25,96	79,77	26,31	79,66	26,65	79,54	27,00	79,42	27,35	79,30	27,69	79,18	28,04	79,06	28,39	84				
85	81,02	26,27	80,72	26,62	80,61	26,97	80,49	27,32	80,37	27,67	80,25	28,02	80,12	28,37	80,00	28,72	85				
86	82,07	26,58	81,67	26,93	81,56	27,29	81,44	27,64	81,31	28,00	81,19	28,35	81,07	28,71	80,94	29,06	86				
87	83,02	26,88	82,62	27,24	82,50	27,60	82,38	27,97	82,26	28,32	82,14	28,68	82,01	29,04	81,88	29,40	87				
88	84,07	27,19	83,57	27,56	83,45	27,92	83,33	28,29	83,21	28,65	83,08	29,01	82,95	29,37	82,82	29,74	88				
89	85,02	27,50	84,52	27,87	84,40	28,24	84,28	28,61	84,15	28,98	84,02	29,34	83,89	29,71	83,76	30,07	89				
90	86,07	27,81	85,47	28,18	85,35	28,56	85,22	28,93	85,10	29,30	84,97	29,67	84,84	30,04	84,71	30,41	90				
91	87,02	28,12	86,42	28,50	86,30	28,87	86,17	29,25	86,04	29,63	85,91	30,00	85,78	30,38	85,65	30,75	91				
92	88,07	28,43	87,37	28,81	87,25	29,19	87,12	29,57	86,99	29,95	86,86	30,33	86,72	30,71	86,59	31,09	92				
93	89,02	28,74	88,32	29,12	88,19	29,51	88,06	29,89	87,93	30,28	87,80	30,66	87,67	31,04	87,53	31,43	93				
94	90,07	29,05	89,27	29,44	89,14	29,83	89,01	30,22	88,88	30,60	88,74	30,99	88,61	31,38	88,47	31,76	94				
95	91,02	29,36	90,22	29,75	90,09	30,14	89,96	30,54	89,82	30,93	89,69	31,32	89,55	31,71	89,41	32,10	95				
96	92,07	29,67	91,17	30,06	91,04	30,46	90,91	30,86	90,77	31,25	90,63	31,65	90,49	32,05	90,35	32,44	96				
97	93,02	29,97	92,12	30,38	91,99	30,78	91,85	31,18	91,71	31,58	91,58	31,98	91,44	32,38	91,29	32,78	97				
98	94,07	30,28	93,07	30,69	92,93	31,09	92,80	31,50	92,66	31,90	92,52	32,31	92,38	32,71	92,24	33,12	98				
99	95,02	30,59	94,02	31,00	93,88	31,41	93,75	31,82	93,61	32,23	93,46	32,64	93,32	33,05	93,18	33,45	99				
100	96,07	30,90	94,97	31,32	94,83	31,72	94,69	32,14	94,55	32,56	94,41	32,97	94,26	33,38	94,12	33,79	100				
101	97,02	31,21	95,92	31,63	95,78	32,05	95,64	32,46	95,50	32,88	95,35	33,30	95,21	33,71	95,06	34,13	101				
102	98,07	31,52	96,87	31,94	96,73	32,36	96,59	32,79	96,44	33,21	96,30	33,63	96,15	34,05	96,00	34,46	102				
103	99,02	31,83	97,82	32,25	97,68	32,68	97,53	33,11	97,39	33,53	97,24	33,96	97,09	34,38	96,94	34,81	103				
104	100,07	32,14	98,77	32,57	98,62	33,00	98,48	33,43	98,33	33,86	98,18	34,29	98,03	34,72	97,88	35,14	104				
105	101,02	32,45	99,73	32,88	99,57	33,32	99,43	33,75	99,28	34,18	99,13	34,62	98,98	35,05	98,82	35,48	105				
106	102,07	32,76	100,68	33,19	100,53	33,63	100,43	34,07	100,28	34,51	100,13	34,95	99,92	35,38	99,76	35,82	106				
107	103,02	33,06	101,63	33,51	101,47	33,95	101,33	34,39	101,18	34,83	101,03	35,28	100,88	35,72	100,73	36,16	107				
108	104,07	33,37	102,58	33,83	102,42	34,27	102,28	34,72	102,13	35,16	101,98	35,61	101,83	36,05	101,68	36,49	108				
109	105,02	33,68	103,53	34,13	103,37	34,59	103,23	35,04	103,08	35,48	102,93	35,94	102,78	36,38	102,63	36,83	109				
110	106,07	33,99	104,48	34,45	104,32	34,90	104,18	35,36	104,03	35,81	103,88	36,27	103,73	36,72	103,58	37,17	110				
111	107,02	34,30	105,43	34,76	105,27	35,22	105,13	35,68	104,98	36,14	104,83	36,60	104,68	37,05	104,53	37,51	111				
112	108,07	34,61	106,38	35,07	106,22	35,54	106,08	36,00	105,93	36,46	105,78	36,93	105,63	37,39	105,48	37,85	112				
113	109,02	34,92	107,33	35,39	107,17	35,85	107,03	36,32	106,88	36,79	106,73	37,26	106,58	37,72	106,43	38,18	113				
114	110,07	35,23	108,28	35,70	108,12	36,17	107,98	36,64	107,83	37,11	107,68	37,58	107,53	38,05	107,38	38,52	114				
115	111,02	35,54	109,23	36,01	109,07	36,49	108,93	36,97	108,78	37,44	108,63	37,91	108,48	38,39	108,33	38,86	115				
116	112,07	35,85	110,18	36,33	110,02	36,81	109,88	37,29	109,73	37,76	109,58	38,24	109,43	38,72	109,28	39,20	116				
117	113,02	36,16	111,13	36,64	110,97	37,12	10														

Distance	20 Degrees								21 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	0.94	0.34	0.94	0.35	0.94	0.35	0.94	0.35	0.93	0.36	0.93	0.36	0.93	0.37	0.93	0.37	
1	0.94	0.34	0.94	0.35	0.94	0.35	0.94	0.35	0.93	0.36	0.93	0.36	0.93	0.37	0.93	0.37	1
2	1.88	0.68	1.88	0.69	1.87	0.70	1.87	0.71	1.87	0.72	1.86	0.73	1.86	0.73	1.86	0.74	2
3	2.82	1.03	2.82	1.04	2.81	1.05	2.81	1.06	2.80	1.08	2.80	1.09	2.79	1.10	2.79	1.11	3
4	3.76	1.37	3.75	1.38	3.75	1.40	3.74	1.42	3.73	1.43	3.73	1.45	3.72	1.47	3.72	1.49	4
5	4.70	1.71	4.69	1.73	4.68	1.75	4.68	1.77	4.67	1.79	4.66	1.81	4.65	1.83	4.64	1.85	5
6	5.64	2.05	5.63	2.08	5.62	2.10	5.61	2.13	5.60	2.15	5.59	2.18	5.58	2.20	5.57	2.22	6
7	6.58	2.39	6.57	2.42	6.56	2.45	6.55	2.48	6.54	2.51	6.52	2.54	6.51	2.57	6.50	2.59	7
8	7.52	2.74	7.51	2.77	7.49	2.80	7.48	2.83	7.47	2.87	7.46	2.90	7.44	2.93	7.43	2.96	8
9	8.46	3.08	8.44	3.12	8.43	3.15	8.42	3.19	8.40	3.23	8.39	3.26	8.37	3.30	8.36	3.34	9
10	9.40	3.42	9.38	3.46	9.37	3.50	9.35	3.54	9.34	3.58	9.32	3.62	9.30	3.67	9.29	3.71	10
11	10.34	3.76	10.32	3.81	10.30	3.85	10.29	3.90	10.27	3.94	10.25	3.99	10.23	4.03	10.22	4.08	11
12	11.28	4.10	11.26	4.15	11.24	4.20	11.22	4.25	11.20	4.30	11.18	4.35	11.17	4.40	11.15	4.45	12
13	12.22	4.45	12.20	4.50	12.18	4.55	12.16	4.61	12.14	4.66	12.12	4.71	12.10	4.77	12.07	4.82	13
14	13.16	4.79	13.14	4.85	13.11	4.90	13.09	4.96	13.07	5.02	13.05	5.07	13.03	5.13	13.00	5.19	14
15	14.10	5.13	14.07	5.19	14.05	5.25	14.03	5.31	14.00	5.38	13.98	5.44	13.96	5.50	13.93	5.56	15
16	15.04	5.47	15.01	5.54	14.99	5.60	14.96	5.67	14.94	5.73	14.91	5.80	14.89	5.86	14.86	5.93	16
17	15.98	5.81	15.95	5.88	15.92	5.95	15.90	6.02	15.87	6.09	15.84	6.16	15.82	6.23	15.79	6.30	17
18	16.92	6.16	16.89	6.23	16.86	6.30	16.83	6.38	16.80	6.45	16.78	6.52	16.75	6.60	16.72	6.67	18
19	17.85	6.50	17.83	6.58	17.80	6.65	17.77	6.73	17.74	6.81	17.71	6.89	17.68	6.96	17.65	7.04	19
20	18.79	6.84	18.76	6.92	18.73	7.00	18.70	7.09	18.67	7.17	18.64	7.25	18.61	7.33	18.58	7.41	20
21	19.73	7.18	19.71	7.27	19.67	7.35	19.64	7.44	19.61	7.53	19.57	7.61	19.54	7.70	19.51	7.78	21
22	20.67	7.52	20.64	7.61	20.61	7.71	20.57	7.80	20.54	7.88	20.50	7.97	20.47	8.06	20.43	8.15	22
23	21.61	7.87	21.58	7.96	21.54	8.06	21.51	8.15	21.47	8.24	21.44	8.34	21.40	8.43	21.36	8.52	23
24	22.55	8.21	22.52	8.31	22.48	8.41	22.45	8.50	22.41	8.60	22.37	8.70	22.33	8.80	22.29	8.89	24
25	23.49	8.55	23.46	8.65	23.42	8.76	23.38	8.86	23.34	8.96	23.30	9.06	23.26	9.16	23.22	9.26	25
26	24.43	8.89	24.39	9.00	24.35	9.11	24.31	9.21	24.27	9.32	24.23	9.42	24.19	9.53	24.15	9.63	26
27	25.37	9.23	25.33	9.35	25.29	9.46	25.25	9.57	25.21	9.68	25.16	9.79	25.12	9.90	25.08	10.00	27
28	26.31	9.58	26.27	9.69	26.23	9.81	26.18	9.92	26.14	10.03	26.10	10.15	26.05	10.26	26.01	10.38	28
29	27.25	9.92	27.21	10.04	27.16	10.16	27.12	10.27	27.07	10.39	27.03	10.51	26.98	10.63	26.94	10.75	29
30	28.19	10.26	28.15	10.38	28.10	10.51	28.05	10.63	28.01	10.75	27.96	10.87	27.91	11.00	27.86	11.12	30
31	29.13	10.60	29.08	10.73	29.04	10.86	28.99	10.98	28.94	11.11	28.89	11.24	28.84	11.36	28.79	11.49	31
32	30.07	10.95	30.02	11.08	29.97	11.21	29.93	11.34	29.87	11.47	29.82	11.60	29.77	11.73	29.72	11.86	32
33	31.01	11.29	30.96	11.42	30.91	11.56	30.86	11.69	30.81	11.83	30.76	11.96	30.70	12.10	30.65	12.23	33
34	31.95	11.63	31.90	11.77	31.85	11.91	31.80	12.05	31.74	12.18	31.69	12.32	31.64	12.46	31.58	12.60	34
35	32.89	11.97	32.84	12.12	32.78	12.26	32.73	12.40	32.68	12.54	32.62	12.69	32.57	12.83	32.51	12.97	35
36	33.83	12.31	33.78	12.46	33.72	12.61	33.67	12.76	33.61	12.90	33.55	13.05	33.50	13.19	33.44	13.34	36
37	34.77	12.66	34.71	12.81	34.66	12.96	34.60	13.11	34.54	13.26	34.48	13.41	34.43	13.56	34.37	13.71	37
38	35.71	13.00	35.62	13.15	35.59	13.31	35.54	13.46	35.48	13.62	35.41	13.77	35.36	13.93	35.29	14.08	38
39	36.65	13.34	36.59	13.50	36.53	13.66	36.47	13.82	36.41	13.98	36.35	14.14	36.29	14.29	36.22	14.45	39
40	37.59	13.68	37.53	13.85	37.47	14.01	37.41	14.17	37.34	14.34	37.28	14.50	37.22	14.66	37.15	14.82	40
41	38.53	14.02	38.47	14.19	38.40	14.36	38.34	14.53	38.28	14.69	38.21	14.86	38.15	15.03	38.08	15.19	41
42	39.47	14.37	39.40	14.54	39.34	14.71	39.28	14.88	39.21	15.05	39.14	15.22	39.08	15.39	39.01	15.56	42
43	40.41	14.71	40.34	14.88	40.28	15.06	40.21	15.23	40.14	15.41	40.08	15.59	40.01	15.76	39.94	15.93	43
44	41.35	15.05	41.28	15.23	41.21	15.41	41.15	15.59	41.08	15.77	41.01	15.95	40.94	16.13	40.87	16.30	44
45	42.29	15.39	42.22	15.58	42.15	15.76	42.08	15.94	42.01	16.13	41.94	16.31	41.87	16.49	41.80	16.67	45
46	43.23	15.73	43.16	15.92	43.09	16.11	43.02	16.30	42.94	16.49	42.87	16.67	42.80	16.86	42.73	17.05	46
47	44.17	16.08	44.10	16.27	44.02	16.46	43.95	16.65	43.88	16.84	43.80	17.04	43.73	17.23	43.65	17.42	47
48	45.11	16.42	45.03	16.62	44.96	16.81	44.89	17.01	44.81	17.20	44.74	17.40	44.66	17.59	44.58	17.79	48
49	46.05	16.76	45.97	16.96	45.90	17.16	45.82	17.36	45.75	17.56	45.67	17.76	45.59	17.96	45.51	18.16	49
50	46.99	17.10	46.91	17.31	46.83	17.51	46.76	17.72	46.68	17.92	46.60	18.12	46.52	18.33	46.44	18.53	50
51	47.93	17.44	47.85	17.65	47.77	17.86	47.69	18.07	47.61	18.28	47.53	18.49	47.45	18.69	47.37	18.90	51
52	48.86	17.79	48.79	18.00	48.71	18.21	48.61	18.42	48.54	18.64	48.47	18.85	48.38	19.06	48.30	19.27	52
53	49.80	18.13	49.73	18.34	49.64	18.56	49.56	18.78	49.48	18.99	49.40	19.21	49.31	19.43	49.23	19.64	53
54	50.74	18.47	50.66	18.69	50.58	18.91	50.50	19.13	50.41	19.35	50.33	19.57	50.24	19.79	50.16	20.01	54
55	51.68	18.81	51.60	19.04	51.52	19.26	51.43	19.49	51.35	19.71	51.26	19.94	51.17	20.16	51.09	20.38	55
56	52.62	19.15	52.54	19.38	52.45	19.61	52.37	19.84	52.28	20.07	52.19	20.30	52.10	20.52	52.01	20.75	56
57	53.56	19.50	53.48	19.73	53.39	19.96	53.30	20.20	53.21	20.43	53.13	20.66	53.03	20.89	52.94	21.12	57
58	54.50	19.84	54.42	20.08	54.33	20.31	54.24	20.55	54.15	20.79	54.06	21.02	53.96	21.26	53.87	21.49	58
59	55.44	20.18	55.35	20.42	55.26	20.66	55.17	20.90	55.08	21.14	54.99	21.38	54.90	21.62	54.80	21.86	59
60	56.38	20.53	56.29	20.77	56.20	21.01	56.11	21.26	56.02	21.50	55.92	21.75	55.83	21.99	55.73	22.23	60
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance
	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.				

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20 Degrees																21 Degrees																Distance	
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		Distance									
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.								
61	57,32	20,86	57,23	21,11	57,14	21,36	57,04	21,61	56,95	21,86	56,85	22,11	56,76	22,36	56,66	22,60	61	57,32	20,86	57,23	21,11	57,14	21,36	57,04	21,61	56,95	21,86	56,85	22,11	56,76	22,36	56,66	22,60
62	58,26	21,21	58,17	21,46	58,07	21,71	57,98	21,97	57,88	22,22	57,79	22,47	57,69	22,73	57,59	22,98	62	58,26	21,21	58,17	21,46	58,07	21,71	57,98	21,97	57,88	22,22	57,79	22,47	57,69	22,73	57,59	22,98
63	59,20	21,55	59,11	21,81	59,01	22,06	58,91	22,32	58,82	22,58	58,72	22,83	58,62	23,09	58,52	23,35	63	59,20	21,55	59,11	21,81	59,01	22,06	58,91	22,32	58,82	22,58	58,72	22,83	58,62	23,09	58,52	23,35
64	60,14	22,29	60,04	22,55	59,95	22,41	59,85	22,67	59,75	22,94	59,65	23,20	59,55	23,46	59,44	23,72	64	60,14	22,29	60,04	22,55	59,95	22,41	59,85	22,67	59,75	22,94	59,65	23,20	59,55	23,46	59,44	23,72
65	61,08	22,53	60,98	22,50	60,88	22,76	60,79	23,03	60,68	23,29	60,58	23,56	60,48	23,82	60,37	24,09	65	61,08	22,53	60,98	22,50	60,88	22,76	60,79	23,03	60,68	23,29	60,58	23,56	60,48	23,82	60,37	24,09
66	62,02	22,57	61,92	22,84	61,82	23,11	61,72	23,38	61,62	23,65	61,51	23,92	61,41	24,19	61,30	24,46	66	62,02	22,57	61,92	22,84	61,82	23,11	61,72	23,38	61,62	23,65	61,51	23,92	61,41	24,19	61,30	24,46
67	62,96	22,92	62,86	23,19	62,76	23,46	62,66	23,74	62,55	24,01	62,45	24,28	62,34	24,56	62,23	24,83	67	62,96	22,92	62,86	23,19	62,76	23,46	62,66	23,74	62,55	24,01	62,45	24,28	62,34	24,56	62,23	24,83
68	63,90	23,26	63,80	23,54	63,69	23,82	63,59	24,09	63,48	24,37	63,38	24,65	63,27	24,92	63,16	25,20	68	63,90	23,26	63,80	23,54	63,69	23,82	63,59	24,09	63,48	24,37	63,38	24,65	63,27	24,92	63,16	25,20
69	64,84	23,60	64,74	23,88	64,63	24,17	64,53	24,45	64,42	24,73	64,31	25,01	64,20	25,29	64,09	25,57	69	64,84	23,60	64,74	23,88	64,63	24,17	64,53	24,45	64,42	24,73	64,31	25,01	64,20	25,29	64,09	25,57
70	65,78	23,94	65,67	24,23	65,57	24,52	65,46	24,80	65,35	25,09	65,24	25,37	65,13	25,66	65,02	25,94	70	65,78	23,94	65,67	24,23	65,57	24,52	65,46	24,80	65,35	25,09	65,24	25,37	65,13	25,66	65,02	25,94
71	66,72	24,28	66,61	24,57	66,50	24,87	66,40	25,15	66,28	25,44	66,17	25,73	66,06	26,02	65,95	26,31	71	66,72	24,28	66,61	24,57	66,50	24,87	66,40	25,15	66,28	25,44	66,17	25,73	66,06	26,02	65,95	26,31
72	67,66	24,63	67,55	24,92	67,44	25,22	67,33	25,51	67,22	25,80	67,11	26,10	66,99	26,39	66,88	26,68	72	67,66	24,63	67,55	24,92	67,44	25,22	67,33	25,51	67,22	25,80	67,11	26,10	66,99	26,39	66,88	26,68
73	68,60	24,97	68,49	25,27	68,38	25,57	68,27	25,86	68,15	26,16	68,04	26,46	67,92	26,76	67,80	27,05	73	68,60	24,97	68,49	25,27	68,38	25,57	68,27	25,86	68,15	26,16	68,04	26,46	67,92	26,76	67,80	27,05
74	69,54	25,31	69,43	25,61	69,31	25,92	69,20	26,22	69,09	26,52	68,97	26,82	68,85	27,12	68,73	27,42	74	69,54	25,31	69,43	25,61	69,31	25,92	69,20	26,22	69,09	26,52	68,97	26,82	68,85	27,12	68,73	27,42
75	70,48	25,65	70,36	25,96	70,25	26,27	70,14	26,57	70,02	26,88	69,90	27,18	69,78	27,49	69,66	27,79	75	70,48	25,65	70,36	25,96	70,25	26,27	70,14	26,57	70,02	26,88	69,90	27,18	69,78	27,49	69,66	27,79
76	71,42	25,99	71,30	26,31	71,19	26,62	71,07	26,93	70,95	27,24	70,83	27,55	70,71	27,85	70,59	28,16	76	71,42	25,99	71,30	26,31	71,19	26,62	71,07	26,93	70,95	27,24	70,83	27,55	70,71	27,85	70,59	28,16
77	72,36	26,34	72,24	26,65	72,12	26,97	72,01	27,28	71,89	27,59	71,77	27,91	71,64	28,22	71,52	28,52	77	72,36	26,34	72,24	26,65	72,12	26,97	72,01	27,28	71,89	27,59	71,77	27,91	71,64	28,22	71,52	28,52
78	73,30	26,68	73,18	27,00	73,06	27,31	72,94	27,63	72,82	27,95	72,70	28,27	72,57	28,59	72,45	28,90	78	73,30	26,68	73,18	27,00	73,06	27,31	72,94	27,63	72,82	27,95	72,70	28,27	72,57	28,59	72,45	28,90
79	74,24	27,02	74,12	27,34	74,00	27,67	73,88	27,99	73,75	28,31	73,63	28,63	73,50	28,95	73,38	29,27	79	74,24	27,02	74,12	27,34	74,00	27,67	73,88	27,99	73,75	28,31	73,63	28,63	73,50	28,95	73,38	29,27
80	75,18	27,36	75,06	27,69	74,93	28,02	74,81	28,34	74,69	28,67	74,56	29,00	74,43	29,37	74,31	29,65	80	75,18	27,36	75,06	27,69	74,93	28,02	74,81	28,34	74,69	28,67	74,56	29,00	74,43	29,37	74,31	29,65
81	76,12	27,70	75,99	28,04	75,87	28,37	75,75	28,70	75,62	29,03	75,49	29,36	75,37	29,69	75,23	30,02	81	76,12	27,70	75,99	28,04	75,87	28,37	75,75	28,70	75,62	29,03	75,49	29,36	75,37	29,69	75,23	30,02
82	77,05	28,05	76,93	28,38	76,81	28,72	76,68	29,05	76,55	29,39	76,43	29,72	76,30	30,05	76,16	30,39	82	77,05	28,05	76,93	28,38	76,81	28,72	76,68	29,05	76,55	29,39	76,43	29,72	76,30	30,05	76,16	30,39
83	77,99	28,39	77,87	28,73	77,74	29,07	77,62	29,41	77,49	29,75	77,36	30,08	77,23	30,42	77,09	30,76	83	77,99	28,39	77,87	28,73	77,74	29,07	77,62	29,41	77,49	29,75	77,36	30,08	77,23	30,42	77,09	30,76
84	78,93	28,73	78,81	29,07	78,68	29,42	78,55	29,76	78,42	30,10	78,29	30,45	78,16	30,79	78,02	31,13	84	78,93	28,73	78,81	29,07	78,68	29,42	78,55	29,76	78,42	30,10	78,29	30,45	78,16	30,79	78,02	31,13
85	79,87	29,07	79,75	29,42	79,62	29,77	79,49	30,11	79,35	30,46	79,22	30,81	79,09	31,15	78,95	31,50	85	79,87	29,07	79,75	29,42	79,62	29,77	79,49	30,11	79,35	30,46	79,22	30,81	79,09	31,15	78,95	31,50
86	80,80	29,41	80,68	29,77	80,55	30,12	80,42	30,47	80,29	30,82	80,15	31,17	80,02	31,52	79,88	31,87	86	80,80	29,41	80,68	29,77	80,55	30,12	80,42	30,47	80,29	30,82	80,15	31,17	80,02	31,52	79,88	31,87
87	81,75	29,76	81,62	30,11	81,49	30,47	81,36	30,82	81,22	31,16	81,09	31,53	80,95	31,89	80,81	32,24	87	81,75	29,76	81,62	30,11	81,49	30,47	81,36	30,82	81,22	31,16	81,09	31,53	80,95	31,89	80,81	32,24
88	82,69	30,10	82,56	30,46	82,43	30,82	82,29	31,18	82,15	31,54	82,02	31,89	81,88	32,25	81,74	32,61	88	82,69	30,10	82,56	30,46	82,43	30,82	82,29	31,18	82,15	31,54	82,02	31,89	81,88	32,25	81,74	32,61
89	83,63	30,44	83,50	30,81	83,36	31,17	83,23	31,53	83,09	31,90	82,95	32,26	82,81	32,62	82,66	32,98	89	83,63	30,44	83,50	30,81	83,36	31,17	83,23	31,53	83,09	31,90	82,95	32,26	82,81	32,62	82,66	32,98
90	84,57	30,78	84,44	31,15	84,30	31,52	84,16	31,89	84,02	32,25	83,88	32,62	83,74	32,99	83,59	33,35	90	84,57	30,78	84,44	31,15	84,30	31,52	84,16	31,89	84,02	32,25	83,88	32,62	83,74	32,99	83,59	33,35
91	85,51	31,12	85,38	31,50	85,24	31,87	85,10																										

Distance	22 Degrees								23 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
1	0,93	0,38	0,93	0,38	0,92	0,38	0,92	0,39	0,92	0,39	0,92	0,40	0,92	0,40	0,92	0,40	1
2	1,85	0,75	1,85	0,76	1,85	0,77	1,84	0,77	1,84	0,78	1,84	0,79	1,83	0,80	1,83	0,81	2
3	2,78	1,12	2,78	1,14	2,77	1,15	2,77	1,16	2,76	1,17	2,76	1,18	2,75	1,20	2,75	1,21	3
4	3,71	1,50	3,70	1,52	3,70	1,53	3,69	1,55	3,68	1,56	3,68	1,58	3,67	1,60	3,66	1,61	4
5	4,64	1,87	4,63	1,89	4,62	1,91	4,61	1,93	4,60	1,95	4,59	1,97	4,59	1,99	4,58	2,01	5
6	5,56	2,25	5,55	2,27	5,54	2,30	5,53	2,32	5,52	2,34	5,51	2,37	5,50	2,39	5,49	2,42	6
7	6,49	2,62	6,48	2,65	6,47	2,68	6,46	2,71	6,44	2,74	6,43	2,76	6,42	2,79	6,41	2,82	7
8	7,42	3,00	7,40	3,03	7,39	3,06	7,38	3,09	7,36	3,13	7,35	3,16	7,34	3,19	7,32	3,22	8
9	8,35	3,37	8,33	3,41	8,32	3,44	8,30	3,48	8,29	3,52	8,27	3,55	8,25	3,59	8,24	3,63	9
10	9,27	3,75	9,26	3,79	9,24	3,83	9,22	3,87	9,21	3,91	9,19	3,95	9,17	3,99	9,15	4,03	10
11	10,20	4,12	10,18	4,17	10,16	4,21	10,14	4,25	10,13	4,30	10,11	4,34	10,09	4,39	10,07	4,43	11
12	11,13	4,50	11,11	4,54	11,09	4,59	11,07	4,64	11,05	4,69	11,03	4,74	11,01	4,79	10,98	4,83	12
13	12,05	4,87	12,03	4,92	12,01	4,97	11,99	5,03	11,97	5,08	11,94	5,13	11,92	5,18	11,90	5,24	13
14	12,98	5,24	12,96	5,30	12,94	5,36	12,91	5,41	12,89	5,47	12,86	5,53	12,84	5,58	12,81	5,64	14
15	13,91	5,62	13,88	5,68	13,86	5,74	13,83	5,80	13,81	5,86	13,78	5,92	13,76	5,98	13,73	6,04	15
16	14,84	5,99	14,81	6,06	14,78	6,12	14,76	6,19	14,73	6,25	14,70	6,32	14,67	6,38	14,65	6,44	16
17	15,76	6,37	15,73	6,44	15,71	6,51	15,68	6,57	15,65	6,64	15,62	6,71	15,59	6,78	15,56	6,85	17
18	16,69	6,74	16,66	6,82	16,63	6,89	16,60	6,96	16,57	7,03	16,54	7,11	16,51	7,18	16,48	7,25	18
19	17,62	7,12	17,59	7,19	17,55	7,27	17,52	7,35	17,49	7,42	17,46	7,50	17,42	7,58	17,39	7,65	19
20	18,54	7,49	18,51	7,57	18,48	7,65	18,44	7,73	18,41	7,82	18,38	7,90	18,34	7,98	18,31	8,06	20
21	19,47	7,87	19,44	7,95	19,40	8,04	19,37	8,12	19,33	8,21	19,30	8,29	19,26	8,37	19,22	8,46	21
22	20,40	8,24	20,36	8,33	20,33	8,42	20,29	8,51	20,25	8,60	20,21	8,69	20,18	8,77	20,14	8,86	22
23	21,33	8,62	21,29	8,71	21,25	8,80	21,21	8,89	21,17	8,99	21,13	9,08	21,09	9,17	21,05	9,26	23
24	22,25	8,99	22,21	9,09	22,17	9,18	22,13	9,28	22,09	9,38	22,05	9,47	22,01	9,57	21,97	9,66	24
25	23,18	9,37	23,14	9,47	23,10	9,57	23,06	9,67	23,01	9,77	22,97	9,87	22,93	9,97	22,88	10,07	25
26	24,11	9,74	24,06	9,84	24,02	9,95	23,98	10,05	23,93	10,16	23,89	10,26	23,84	10,37	23,80	10,47	26
27	25,03	10,11	24,99	10,22	24,95	10,33	24,90	10,44	24,85	10,55	24,81	10,66	24,76	10,77	24,71	10,87	27
28	25,96	10,49	25,92	10,60	25,87	10,72	25,82	10,83	25,77	10,94	25,73	11,05	25,68	11,16	25,63	11,28	28
29	26,89	10,86	26,84	10,98	26,79	11,10	26,74	11,21	26,70	11,33	26,65	11,45	26,60	11,56	26,54	11,68	29
30	27,82	11,24	27,77	11,36	27,72	11,48	27,67	11,60	27,62	11,72	27,56	11,84	27,51	11,96	27,46	12,08	30
31	28,74	11,61	28,69	11,74	28,64	11,86	28,59	11,99	28,54	12,11	28,48	12,24	28,43	12,36	28,37	12,49	31
32	29,67	11,99	29,62	12,12	29,56	12,25	29,51	12,38	29,46	12,50	29,40	12,63	29,35	12,76	29,29	12,89	32
33	30,60	12,36	30,54	12,50	30,49	12,63	30,43	12,76	30,38	12,89	30,32	13,03	30,26	13,16	30,21	13,29	33
34	31,52	12,74	31,47	12,87	31,41	13,01	31,36	13,15	31,30	13,28	31,24	13,42	31,18	13,56	31,12	13,69	34
35	32,45	13,11	32,39	13,25	32,34	13,39	32,28	13,54	32,22	13,68	32,16	13,82	32,10	13,96	32,04	14,10	35
36	33,38	13,49	33,32	13,63	33,26	13,78	33,20	13,92	33,14	14,07	33,08	14,21	33,01	14,36	32,95	14,50	36
37	34,31	13,86	34,25	14,01	34,18	14,16	34,12	14,31	34,06	14,46	34,00	14,61	33,93	14,75	33,87	14,90	37
38	35,23	14,24	35,17	14,39	35,11	14,54	35,04	14,69	34,98	14,85	34,91	15,00	34,85	15,15	34,78	15,30	38
39	36,16	14,61	36,10	14,77	36,03	14,92	35,97	15,08	35,90	15,24	35,83	15,40	35,77	15,55	35,70	15,87	39
40	37,09	14,98	37,02	15,15	36,96	15,30	36,89	15,47	36,82	15,63	36,75	15,79	36,68	15,95	36,61	16,11	40
41	38,01	15,36	37,95	15,52	37,88	15,69	37,81	15,86	37,74	16,02	37,67	16,19	37,60	16,35	37,53	16,51	41
42	38,94	15,73	38,87	15,90	38,80	16,07	38,73	16,24	38,66	16,41	38,59	16,59	38,52	16,75	38,44	16,92	42
43	39,87	16,10	39,80	16,28	39,73	16,45	39,66	16,63	39,58	16,80	39,51	16,97	39,43	17,15	39,36	17,32	43
44	40,80	16,48	40,72	16,66	40,65	16,84	40,58	17,02	40,50	17,19	40,43	17,37	40,35	17,54	40,27	17,72	44
45	41,72	16,86	41,65	17,04	41,57	17,22	41,50	17,40	41,42	17,58	41,35	17,76	41,27	17,94	41,19	18,12	45
46	42,65	17,23	42,58	17,42	42,50	17,60	42,42	17,79	42,34	17,97	42,27	18,16	42,18	18,34	42,10	18,53	46
47	43,58	17,61	43,50	17,80	43,42	17,99	43,34	18,18	43,26	18,37	43,18	18,55	43,10	18,74	43,02	18,93	47
48	44,51	17,98	44,43	18,18	44,35	18,37	44,27	18,56	44,18	18,76	44,10	18,95	44,02	19,14	43,93	19,33	48
49	45,43	18,36	45,35	18,55	45,27	18,75	45,19	18,95	45,11	19,15	45,02	19,34	44,94	19,54	44,85	19,73	49
50	46,36	18,73	46,28	18,93	46,19	19,13	46,11	19,34	46,03	19,54	45,94	19,74	45,85	19,94	45,77	20,14	50
51	47,29	19,11	47,20	19,31	47,12	19,52	47,03	19,72	46,95	19,93	46,86	20,13	46,77	20,34	46,68	20,54	51
52	48,21	19,48	48,13	19,69	48,04	19,90	47,95	20,11	47,87	20,32	47,78	20,53	47,69	20,74	47,60	20,94	52
53	49,14	19,86	49,05	20,07	48,97	20,18	48,88	20,50	48,79	20,71	48,70	20,92	48,60	21,13	48,51	21,35	53
54	50,07	20,23	49,98	20,45	49,89	20,66	49,80	20,88	49,71	21,10	49,62	21,32	49,52	21,53	49,43	21,75	54
55	51,00	20,60	50,90	20,83	50,81	21,05	50,72	21,27	50,63	21,49	50,53	21,71	50,44	21,93	50,34	22,15	55
56	51,92	20,98	51,83	21,20	51,74	21,43	51,64	21,66	51,55	21,88	51,45	22,11	51,36	22,33	51,26	22,55	56
57	52,85	21,35	52,76	21,58	52,67	21,81	52,57	22,04	52,47	22,27	52,37	22,50	52,27	22,73	52,17	22,96	57
58	53,77	21,73	53,68	21,96	53,59	22,20	53,49	22,43	53,39	22,66	53,29	22,90	53,19	23,13	53,09	23,36	58
59	54,70	22,10	54,61	22,34	54,51	22,58	54,41	22,82	54,31	23,05	54,21	23,29	54,11	23,53	54,00	23,76	59
60	55,63	22,48	55,53	22,72	55,43	22,96	55,33	23,20	55,23	23,44	55,13						

TRAVERSE TABLE, 67.

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22 Degrees								23 Degrees								24 Degrees															
0 Min.				15 Min.				30 Min.				45 Min.				0 Min.				15 Min.				30 Min.				45 Min.			
Lat.		Dep.		Lat.		Dep.		Lat.		Dep.		Lat.		Dep.		Lat.		Dep.		Lat.		Dep.		Lat.		Dep.					
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.					
Lat.		Dep.		Lat.		Dep.		Lat.		Dep.		Lat.		Dep.		Lat.		Dep.		Lat.		Dep.		Lat.		Dep.					
61	56,56	22,85	56,46	23,10	56,36	23,34	56,25	23,59	56,15	23,83	56,05	24,08	55,94	24,32	55,83	24,57	61	56,15	23,83	56,05	24,08	55,94	24,32	55,83	24,57	61					
62	57,49	23,23	57,38	23,48	57,28	23,73	57,18	23,98	57,07	24,22	56,97	24,47	56,86	24,72	56,75	24,97	62	57,07	24,22	56,97	24,47	56,86	24,72	56,75	24,97	62					
63	58,41	23,60	58,31	23,86	58,21	24,11	58,10	24,37	57,99	24,62	57,88	24,87	57,78	25,12	57,66	25,37	63	57,99	24,62	57,88	24,87	57,78	25,12	57,66	25,37	63					
64	59,34	23,98	59,23	24,23	59,13	24,49	59,02	24,75	58,91	25,01	58,80	25,26	58,69	25,52	58,58	25,78	64	58,91	25,01	58,80	25,26	58,69	25,52	58,58	25,78	64					
65	60,27	24,35	60,16	24,61	60,05	24,87	59,94	25,14	59,83	25,40	59,72	25,66	59,61	25,92	59,49	26,18	65	59,83	25,40	59,72	25,66	59,61	25,92	59,49	26,18	65					
66	61,19	24,72	61,08	24,99	60,98	25,26	60,87	25,52	60,75	25,79	60,64	26,05	60,53	26,32	60,41	26,58	66	60,75	25,79	60,64	26,05	60,53	26,32	60,41	26,58	66					
67	62,12	25,10	62,01	25,37	61,90	25,63	61,79	25,91	61,67	26,18	61,56	26,45	61,44	26,72	61,32	26,99	67	61,67	26,18	61,56	26,45	61,44	26,72	61,32	26,99	67					
68	63,05	25,47	62,94	25,75	62,82	26,02	62,71	26,30	62,59	26,57	62,48	26,84	62,36	27,12	62,24	27,39	68	62,59	26,57	62,48	26,84	62,36	27,12	62,24	27,39	68					
69	63,98	25,85	63,86	26,13	63,75	26,41	63,63	26,68	63,52	26,96	63,40	27,23	63,28	27,52	63,15	27,79	69	63,52	26,96	63,40	27,23	63,28	27,52	63,15	27,79	69					
70	64,91	26,22	64,79	26,51	64,67	26,79	64,55	27,07	64,44	27,35	64,32	27,63	64,19	27,91	64,07	28,19	70	64,44	27,35	64,32	27,63	64,19	27,91	64,07	28,19	70					
71	65,83	26,60	65,71	26,89	65,60	27,17	65,48	27,46	65,36	27,74	65,23	28,03	65,11	28,31	64,99	28,60	71	65,36	27,74	65,23	28,03	65,11	28,31	64,99	28,60	71					
72	66,76	26,97	66,64	27,26	66,52	27,55	66,40	27,84	66,28	28,13	66,15	28,42	66,03	28,71	65,90	29,00	72	66,28	28,13	66,15	28,42	66,03	28,71	65,90	29,00	72					
73	67,69	27,35	67,57	27,64	67,44	27,94	67,32	28,22	67,20	28,52	67,07	28,82	66,95	29,11	66,82	29,40	73	67,20	28,52	67,07	28,82	66,95	29,11	66,82	29,40	73					
74	68,61	27,72	68,49	28,02	68,37	28,32	68,24	28,62	68,12	28,91	67,99	29,21	67,86	29,51	67,73	29,81	74	68,12	28,91	67,99	29,21	67,86	29,51	67,73	29,81	74					
75	69,54	28,10	69,42	28,40	69,29	28,70	69,17	29,00	69,04	29,30	68,91	29,61	68,78	29,91	68,65	30,21	75	69,04	29,30	68,91	29,61	68,78	29,91	68,65	30,21	75					
76	70,47	28,47	70,34	28,78	70,21	29,08	70,09	29,39	69,96	29,69	69,83	30,00	69,70	30,31	69,56	30,61	76	69,96	29,69	69,83	30,00	69,70	30,31	69,56	30,61	76					
77	71,39	28,85	71,27	29,16	71,14	29,47	71,01	29,78	70,88	30,09	70,75	30,40	70,61	30,71	70,48	31,01	77	70,88	30,09	70,75	30,40	70,61	30,71	70,48	31,01	77					
78	72,32	29,22	72,19	29,54	72,06	29,85	71,93	30,16	71,80	30,48	71,67	30,79	71,53	31,11	71,39	31,42	78	71,80	30,48	71,67	30,79	71,53	31,11	71,39	31,42	78					
79	73,25	29,59	73,12	29,91	72,99	30,23	72,85	30,55	72,72	30,87	72,59	31,19	72,45	31,50	72,31	31,82	79	72,72	30,87	72,59	31,19	72,45	31,50	72,31	31,82	79					
80	74,17	29,97	74,04	30,29	73,91	30,61	73,78	30,94	73,64	31,26	73,50	31,58	73,37	31,90	73,23	32,22	80	73,64	31,26	73,50	31,58	73,37	31,90	73,23	32,22	80					
81	75,10	30,34	74,97	30,67	74,83	31,00	74,70	31,32	74,56	31,65	74,42	31,97	74,28	32,30	74,14	32,62	81	74,56	31,65	74,42	31,97	74,28	32,30	74,14	32,62	81					
82	76,03	30,72	75,89	31,05	75,76	31,38	75,62	31,71	75,48	32,04	75,34	32,37	75,20	32,70	75,06	33,03	82	75,48	32,04	75,34	32,37	75,20	32,70	75,06	33,03	82					
83	76,96	31,09	76,82	31,43	76,68	31,76	76,54	32,09	76,40	32,43	76,26	32,76	76,12	33,10	75,97	33,43	83	76,40	32,43	76,26	32,76	76,12	33,10	75,97	33,43	83					
84	77,88	31,47	77,75	31,81	77,61	32,15	77,47	32,48	77,32	32,82	77,18	33,15	77,03	33,50	76,89	33,83	84	77,32	32,82	77,18	33,15	77,03	33,50	76,89	33,83	84					
85	78,81	31,84	78,67	32,19	78,53	32,53	78,39	32,87	78,24	33,21	78,10	33,55	77,95	33,90	77,80	34,24	85	78,24	33,21	78,10	33,55	77,95	33,90	77,80	34,24	85					
86	79,74	32,22	79,60	32,56	79,45	32,91	79,31	33,26	79,16	33,60	79,02	33,95	78,87	34,29	78,71	34,64	86	79,16	33,60	79,02	33,95	78,87	34,29	78,71	34,64	86					
87	80,66	32,59	80,52	32,94	80,38	33,29	80,23	33,64	80,08	34,00	79,94	34,34	79,78	34,69	79,63	35,04	87	80,08	34,00	79,94	34,34	79,78	34,69	79,63	35,04	87					
88	81,59	32,97	81,45	33,32	81,30	33,68	81,16	34,03	81,00	34,39	80,86	34,73	80,71	35,09	80,55	35,44	88	81,00	34,39	80,86	34,73	80,71	35,09	80,55	35,44	88					
89	82,52	33,34	82,37	33,70	82,23	34,06	82,08	34,42	81,93	34,78	81,77	35,13	81,62	35,49	81,46	35,85	89	81,93	34,78	81,77	35,13	81,62	35,49	81,46	35,85	89					
90	83,45	33,72	83,30	34,08	83,15	34,44	83,00	34,81	82,85	35,17	82,69	35,53	82,54	35,89	82,38	36,25	90	82,85	35,17	82,69	35,53	82,54	35,89	82,38	36,25	90					
91	84,37	34,09	84,22	34,46	84,07	34,82	83,92	35,19	83,77	35,56	83,61	35,92	83,46	36,29	83,29	36,65	91	83,77	35,56	83,61	35,92	83,46	36,29	83,29	36,65	91					
92	85,30	34,46	85,15	34,84	85,00	35,21	84,84	35,57	84,69	35,95	84,53	36,32	84,37	36,69	84,21	37,05	92	84,69	35,95	84,53	36,32	84,37	36,69	84,21	37,05	92					
93	86,23	34,84	86,08	35,22	85,92	35,59	85,77	35,97	85,61	36,34	85,45	36,71	85,29	37,09	85,12	37,46	93	85,61	36,34	85,45	36,71	85,29	37,09	85,12	37,46	93					
94	87,16	35,21	87,00	35,59	86,85	35,97	86,69	36,35	86,53	36,73	86,37	37,11	86,20	37,48	86,04	37,86	94	86,53	36,73	86,37	37,11	86,20	37,48	86,04	37,86	94					
95	88,08	35,59	87,92	35,97	87,77	36,35	87,61	36,74	87,45	37,12	87,29	37,50	87,12	37,88	86,95	38,26	95	87,45	37,12	87,29	37,50	87,12	37,88	86,95	38,26	95					
96	88,91	35,96	88,85	36,35	88,69	36,74	88,53	37,12	88,37	37,51	88,21	37,90	88,04	38,28	87,87	38,67	96	88,37	37,51	88,21	37,90	88,04	38,28	87,87	38,67	96					
97	89,84	36,34	89,78	36,73	89,62	37,12	89,45	37,51	89,29	37,90	89,12	38,29	88,95	38,68	88,78	39,07	97	89,29	37,90	89,12	38,29	88,95	38,68	88,78	39,07	97					
98	90,76	36,71	90,70	37,11	90,54	37,50	90,38	37,90	90,21	38,29	90,04	38,69	89,87	39,08	89,70	39,47	98	90,21	38,29	90,04	38,69	89,87	39,08	89,70	39,47	98					

Distance	24 Degrees								45	25 Degrees								47	Distance
	0 Min.		15 Min.		30 Min.		45 Min.			0 Min.		15 Min.		30 Min.		45 Min.			
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
1	0,91	0,41	0,91	0,41	0,91	0,42	0,91	0,42	0,91	0,42	0,90	0,43	0,90	0,43	0,90	0,43	0,90	0,43	1
2	1,83	0,81	1,82	0,82	1,82	0,83	1,82	0,84	1,81	0,85	1,81	0,85	1,81	0,86	1,80	0,87	1,80	0,87	2
3	2,74	1,22	2,74	1,23	2,73	1,24	2,72	1,26	2,72	1,27	2,71	1,28	2,71	1,29	2,70	1,30	2,70	1,30	3
4	3,65	1,63	3,65	1,64	3,64	1,66	3,63	1,68	3,63	1,69	3,62	1,71	3,61	1,72	3,60	1,74	3,60	1,74	4
5	4,57	2,03	4,56	2,05	4,55	2,07	4,54	2,09	4,58	2,11	4,52	2,13	4,51	2,15	4,50	2,17	4,50	2,17	5
6	5,48	2,44	5,47	2,46	5,46	2,49	5,45	2,51	5,44	2,54	5,43	2,56	5,42	2,58	5,40	2,64	5,40	2,64	6
7	6,40	2,85	6,38	2,88	6,37	2,90	6,36	2,93	6,34	2,96	6,33	2,99	6,32	3,01	6,31	3,04	6,31	3,04	7
8	7,31	3,25	7,29	3,29	7,28	3,32	7,27	3,35	7,25	3,38	7,24	3,41	7,22	3,44	7,21	3,48	7,21	3,48	8
9	8,22	3,66	8,21	3,70	8,19	3,73	8,17	3,77	8,16	3,80	8,14	3,84	8,12	3,88	8,11	3,91	8,11	3,91	9
10	9,14	4,07	9,12	4,11	9,10	4,15	9,08	4,19	9,06	4,23	9,05	4,27	9,03	4,31	9,01	4,35	9,01	4,35	10
11	10,05	4,47	10,03	4,52	10,01	4,56	9,99	4,61	9,97	4,65	9,95	4,69	9,93	4,74	9,91	4,78	9,91	4,78	11
12	10,96	4,88	10,94	4,93	10,92	4,98	10,90	5,02	10,88	5,07	10,85	5,12	10,83	5,17	10,81	5,21	10,81	5,21	12
13	11,88	5,29	11,85	5,34	11,83	5,39	11,81	5,44	11,78	5,49	11,76	5,55	11,73	5,60	11,71	5,65	11,71	5,65	13
14	12,79	5,69	12,76	5,75	12,74	5,81	12,71	5,86	12,69	5,92	12,66	5,97	12,64	6,03	12,61	6,08	12,61	6,08	14
15	13,70	6,10	13,68	6,16	13,65	6,22	13,62	6,28	13,59	6,34	13,57	6,40	13,54	6,46	13,51	6,52	13,51	6,52	15
16	14,62	6,51	14,59	6,57	14,56	6,64	14,53	6,70	14,50	6,76	14,47	6,83	14,44	6,89	14,41	6,95	14,41	6,95	16
17	15,53	6,91	15,50	6,98	15,47	7,05	15,44	7,12	15,41	7,19	15,37	7,25	15,35	7,32	15,31	7,39	15,31	7,39	17
18	16,44	7,32	16,41	7,39	16,38	7,47	16,35	7,54	16,31	7,61	16,28	7,68	16,25	7,75	16,21	7,82	16,21	7,82	18
19	17,36	7,73	17,32	7,80	17,29	7,88	17,25	7,96	17,22	8,03	17,18	8,11	17,15	8,18	17,11	8,26	17,11	8,26	19
20	18,27	8,14	18,24	8,21	18,20	8,29	18,16	8,37	18,13	8,45	18,09	8,53	18,05	8,61	18,01	8,69	18,01	8,69	20
21	19,18	8,54	19,15	8,63	19,11	8,71	19,07	8,79	19,03	8,88	18,99	8,96	18,96	9,04	18,92	9,12	18,92	9,12	21
22	20,10	8,95	20,06	9,04	20,02	9,12	19,98	9,21	19,94	9,30	19,90	9,39	19,86	9,47	19,82	9,56	19,82	9,56	22
23	21,01	9,36	20,97	9,45	20,94	9,55	20,89	9,63	20,84	9,72	20,80	9,81	20,76	9,90	20,72	9,99	20,72	9,99	23
24	21,93	9,76	21,88	9,86	21,85	9,96	21,80	10,05	21,75	10,14	21,71	10,24	21,66	10,33	21,62	10,43	21,62	10,43	24
25	22,84	10,17	22,79	10,27	22,75	10,38	22,70	10,47	22,66	10,57	22,61	10,67	22,57	10,77	22,52	10,86	22,52	10,86	25
26	23,75	10,58	23,71	10,68	23,66	10,79	23,61	10,89	23,56	10,99	23,51	11,09	23,47	11,20	23,42	11,30	23,42	11,30	26
27	24,67	10,98	24,62	11,09	24,57	11,21	24,52	11,31	24,47	11,41	24,41	11,52	24,37	11,63	24,32	11,73	24,32	11,73	27
28	25,58	11,39	25,53	11,50	25,48	11,62	25,43	11,73	25,37	11,84	25,32	11,95	25,28	12,06	25,22	12,17	25,22	12,17	28
29	26,49	11,80	26,44	11,91	26,39	12,04	26,34	12,14	26,28	12,26	26,23	12,37	26,18	12,49	26,12	12,60	26,12	12,60	29
30	27,41	12,20	27,35	12,32	27,30	12,44	27,24	12,56	27,19	12,68	27,13	12,80	27,08	12,92	27,02	13,03	27,02	13,03	30
31	28,32	12,61	28,26	12,73	28,21	12,86	28,15	12,98	28,10	13,10	28,04	13,22	27,98	13,35	27,92	13,47	27,92	13,47	31
32	29,23	13,02	29,18	13,14	29,12	13,27	29,06	13,40	29,00	13,53	28,94	13,65	28,88	13,78	28,82	13,90	28,82	13,90	32
33	30,15	13,42	30,09	13,55	30,03	13,69	29,97	13,82	29,91	13,95	29,85	14,08	29,79	14,21	29,72	14,34	29,72	14,34	33
34	31,06	13,83	31,00	13,97	30,94	14,10	30,88	14,24	30,81	14,37	30,75	14,51	30,69	14,64	30,62	14,77	30,62	14,77	34
35	31,97	14,24	31,91	14,38	31,85	14,51	31,78	14,66	31,72	14,79	31,65	14,93	31,59	15,07	31,53	15,21	31,53	15,21	35
36	32,89	14,64	32,82	14,79	32,76	14,93	32,69	15,07	32,63	15,22	32,56	15,36	32,50	15,50	32,43	15,64	32,43	15,64	36
37	33,80	15,05	33,73	15,20	33,67	15,35	33,60	15,49	33,53	15,64	33,46	15,79	33,40	15,93	33,33	16,08	33,33	16,08	37
38	34,72	15,46	34,65	15,61	34,58	15,76	34,51	15,91	34,44	16,06	34,37	16,21	34,30	16,36	34,23	16,51	34,23	16,51	38
39	35,63	15,86	35,56	16,02	35,49	16,18	35,42	16,33	35,34	16,49	35,28	16,64	35,21	16,79	35,13	16,94	35,13	16,94	39
40	36,54	16,27	36,47	16,43	36,40	16,59	36,33	16,75	36,25	16,91	36,18	17,07	36,10	17,22	36,03	17,38	36,03	17,38	40
41	37,46	16,68	37,38	16,84	37,31	17,00	37,23	17,17	37,16	17,33	37,08	17,49	37,01	17,65	36,93	17,81	36,93	17,81	41
42	38,37	17,08	38,29	17,25	38,22	17,42	38,14	17,58	38,06	17,75	37,99	17,92	37,92	18,08	37,83	18,25	37,83	18,25	42
43	39,28	17,49	39,20	17,66	39,13	17,83	39,05	18,00	38,97	18,18	38,89	18,34	38,82	18,51	38,73	18,68	38,73	18,68	43
44	40,20	17,90	40,12	18,07	40,04	18,25	39,96	18,42	39,88	18,60	39,79	18,77	39,72	18,94	39,63	19,12	39,63	19,12	44
45	41,11	18,30	41,03	18,48	40,95	18,66	40,87	18,84	40,78	19,02	40,70	19,20	40,62	19,38	40,53	19,55	40,53	19,55	45
46	42,02	18,71	41,94	18,89	41,86	19,08	41,77	19,26	41,69	19,45	41,60	19,63	41,52	19,81	41,43	19,99	41,43	19,99	46
47	42,94	19,12	42,85	19,30	42,77	19,49	42,68	19,68	42,59	19,87	42,51	20,05	42,42	20,24	42,33	20,42	42,33	20,42	47
48	43,85	19,52	43,76	19,72	43,68	19,91	43,59	20,10	43,50	20,29	43,41	20,48	43,32	20,67	43,23	20,85	43,23	20,85	48
49	44,76	19,93	44,68	20,13	44,59	20,32	44,50	20,52	44,41	20,71	44,31	20,91	44,23	21,10	44,13	21,29	44,13	21,29	49
50	45,68	20,34	45,59	20,54	45,50	20,74	45,41	20,93	45,32	21,13	45,22	21,33	45,14	21,53	45,04	21,72	45,04	21,72	50
51	46,59	20,74	46,50	20,95	46,41	21,15	46,32	21,35	46,22	21,55	46,13	21,76	46,03	21,96	45,94	22,16	45,94	22,16	51
52	47,51	21,15	47,41	21,36	47,32	21,57	47,22	21,77	47,13	21,98	47,03	22,18	46,94	22,39	46,84	22,59	46,84	22,59	52
53	48,42	21,56	48,32	21,77	48,23	21,98	48,13	22,19	48,03	22,40	47,94	22,61	47,84	22,82	47,74	23,03	47,74	23,03	53
54	49,33	21,96	49,23	22,18	49,14	22,40	49,04	22,61	48,95	22,82	48,84	23,04	48,74	23,25	48,64	23,46	48,64	23,46	54
55	50,25	22,37	50,15	22,59	50,05	22,81	49,95	23,03	49,85	23,24	49,74	23,46	49,65	23,68	49,54	23,90	49,54	23,90	55
56	51,16	22,78	51,06	23,00	50,96	23,23	50,86	23,45	50,75	23,67	50,65	23,89	50,55	24,11	50,44	24,33	50,44	24,33	56
57	52,07	23,18	51,97	23,41	51,87	23,64	51,76	23,87	51,66	24,09	51,51								

TRAVERSE TABLE, 67.

111

24 Degrees												45		25 Degrees												47		Distance
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.						
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.					
61	55,73	24,81	55,62	25,06	55,51	25,30	55,40	25,54	55,29	25,78	55,17	26,02	55,06	26,26	54,94	26,51	61											
62	56,64	25,22	56,53	25,47	56,42	25,71	56,30	25,96	56,19	26,20	56,08	26,45	55,96	26,69	55,84	26,94	62											
63	57,56	25,63	57,44	25,88	57,33	26,13	57,21	26,38	57,10	26,63	56,98	26,88	56,86	27,12	56,75	27,37	63											
64	58,47	26,03	58,35	26,29	58,24	26,54	58,12	26,80	58,00	27,05	57,88	27,30	57,77	27,56	57,65	27,80	64											
65	59,38	26,44	59,27	26,70	59,15	26,96	59,03	27,22	58,91	27,47	58,79	27,73	58,67	27,99	58,55	28,24	65											
66	60,30	26,85	60,18	27,11	60,06	27,37	59,94	27,63	59,82	27,90	59,69	28,16	59,57	28,42	59,45	28,67	66											
67	61,21	27,26	61,09	27,52	60,97	27,79	60,84	28,05	60,72	28,32	60,60	28,58	60,48	28,85	60,35	29,11	67											
68	62,13	27,66	62,00	27,93	61,88	28,20	61,75	28,47	61,63	28,74	61,50	29,01	61,38	29,28	61,25	29,54	68											
69	63,04	28,07	62,91	28,34	62,79	28,62	62,66	28,89	62,53	29,16	62,40	29,44	62,28	29,71	62,15	29,97	69											
70	63,95	28,47	63,82	28,75	63,70	29,03	63,57	29,31	63,44	29,58	63,31	29,86	63,18	30,14	63,05	30,41	70											
71	64,86	28,88	64,74	29,16	64,61	29,44	64,48	29,73	64,35	30,01	64,22	30,29	64,08	30,57	63,95	30,85	71											
72	65,78	29,29	65,65	29,57	65,52	29,86	65,39	30,14	65,25	30,43	65,12	30,72	64,99	30,99	64,85	31,28	72											
73	66,69	29,69	66,56	29,98	66,43	30,27	66,29	30,56	66,16	30,85	66,02	31,15	65,89	31,43	65,75	31,71	73											
74	67,61	30,10	67,47	30,39	67,34	30,69	67,20	30,98	67,07	31,28	66,94	31,58	66,79	31,86	66,65	32,15	74											
75	68,52	30,51	68,39	30,81	68,25	31,10	68,11	31,40	67,97	31,70	67,84	32,00	67,70	32,29	67,55	32,58	75											
76	69,43	30,91	69,30	31,22	69,16	31,52	69,02	31,82	68,88	32,12	68,75	32,42	68,60	32,72	68,46	33,02	76											
77	70,35	31,32	70,21	31,63	70,07	31,93	69,93	32,24	69,78	32,54	69,65	32,85	69,50	33,15	69,36	33,45	77											
78	71,26	31,73	71,12	32,04	70,98	32,35	70,83	32,66	70,69	32,97	70,55	33,28	70,41	33,58	70,26	33,88	78											
79	72,18	32,14	72,03	32,45	71,89	32,76	71,74	33,08	71,60	33,39	71,46	33,70	71,31	34,01	71,16	34,32	79											
80	73,08	32,54	72,94	32,86	72,80	33,18	72,65	33,50	72,51	33,81	72,36	34,13	72,21	34,44	72,06	34,76	80											
81	74,00	32,95	73,85	33,27	73,71	33,59	73,56	33,91	73,41	34,23	73,26	34,55	73,11	34,87	72,96	35,19	81											
82	74,91	33,35	74,77	33,68	74,62	34,00	74,47	34,33	74,32	34,66	74,17	34,98	74,01	35,30	73,86	35,62	82											
83	75,83	33,76	75,68	34,09	75,53	34,42	75,38	34,75	75,22	35,08	75,07	35,41	74,92	35,73	74,76	36,06	83											
84	76,74	34,17	76,59	34,50	76,44	34,84	76,28	35,17	76,13	35,50	75,97	35,83	75,82	36,17	75,66	36,49	84											
85	77,65	34,57	77,50	34,91	77,35	35,25	77,19	35,59	77,04	35,93	76,88	36,26	76,72	36,60	76,56	36,93	85											
86	78,57	34,98	78,41	35,32	78,26	35,67	78,10	36,01	77,94	36,35	77,78	36,69	77,63	37,03	77,46	37,36	86											
87	79,48	35,39	79,33	35,74	79,17	36,08	79,01	36,43	78,85	36,77	78,69	37,12	78,53	37,46	78,36	37,79	87											
88	80,40	35,80	80,24	36,15	80,08	36,50	79,92	36,85	79,75	37,19	79,59	37,54	79,43	37,89	79,26	38,23	88											
89	81,31	36,20	81,15	36,56	80,99	36,91	80,83	37,26	80,66	37,62	80,49	37,97	80,33	38,33	80,16	38,66	89											
90	82,22	36,61	82,06	36,97	81,90	37,32	81,73	37,68	81,57	38,04	81,40	38,39	81,23	38,75	81,06	39,10	90											
91	83,13	37,01	82,97	37,38	82,81	37,74	82,64	38,10	82,47	38,46	82,31	38,82	82,14	39,18	81,96	39,54	91											
92	84,05	37,42	83,88	37,79	83,72	38,15	83,55	38,52	83,38	38,88	83,21	39,25	83,04	39,61	82,87	39,97	92											
93	84,96	37,83	84,79	38,20	84,63	38,57	84,46	38,94	84,29	39,31	84,11	39,67	83,94	40,04	83,77	40,40	93											
94	85,88	38,24	85,71	38,61	85,54	38,98	85,37	39,36	85,19	39,73	85,02	40,10	84,85	40,47	84,67	40,84	94											
95	86,79	38,61	86,62	39,02	86,45	39,40	86,27	39,76	86,10	40,15	85,92	40,53	85,75	40,90	85,57	41,27	95											
96	87,70	39,02	87,52	39,43	87,36	39,81	87,18	40,18	87,00	40,57	86,83	40,95	86,65	41,33	86,47	41,71	96											
97	88,62	39,43	88,44	39,84	88,27	40,23	88,09	40,60	87,91	41,00	87,73	41,38	87,55	41,76	87,37	42,14	97											
98	89,53	39,83	89,35	40,25	89,18	40,64	89,00	41,02	88,82	41,42	88,63	41,81	88,46	42,19	88,27	42,57	98											
99	90,44	40,24	90,26	40,66	90,09	41,06	89,91	41,44	89,73	41,84	89,54	42,23	89,36	42,62	89,17	43,01	99											
100	91,35	40,67	91,18	41,07	91,00	41,47	90,81	41,87	90,63	42,26	90,45	42,66	90,26	43,05	90,07	43,45	100											
101	92,27	41,08	92,09	41,48	91,91	41,88	91,72	42,29	91,54	42,69	91,35	43,08	91,16	43,48	90,97	43,88	101											
102	93,18	41,49	93,00	41,89	92,82	42,30	92,63	42,70	92,44	43,11	92,25	43,51	92,07	43,91	91,87	44,31	102											
103	94,10	41,90	93,91	42,31	93,73	42,71	93,54	43,12	93,35	43,53	93,16	43,94	92,97	44,34	92,77	44,75	103											
104	95,01	42,30	94,82	42,72	94,64	43,13	94,45	43,54	94,26	43,95	94,06	44,37	93,87	44,78	93,67	45,18	104											
105	95,93	42,71	95,74	43,13	95,55	43,54	95,35	43,96	95,16	44,38	94,97	44,79	94,77	45,21	94,58	45,62	105											
106	96,83	43,12	96,65	43,54	96,46	43,96	96,26	44,38	96,07	44,80	95,87	45,22	95,68	45,64	95,48	46,05	106											
107	97,75	43,52	97,56	43,95	97,37	44,37	97,17	44,80	96,97	45,22	96,77	45,65	96,59	46,07	96,38	46,48	107											
108	98,67	43,93	98,47	44,36	98,28	44,79	98,08	45,22	97,88	45,65	97,68	46,07	97,49															

Distance	26 Degrees								27 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0,90	0,44	0,90	0,44	0,90	0,45	0,89	0,45	0,89	0,45	0,89	0,46	0,89	0,46	0,89	0,47	1
2	1,80	0,88	1,79	0,89	1,79	0,89	1,79	0,90	1,78	0,91	1,78	0,92	1,77	0,92	1,77	0,93	2
3	2,70	1,32	2,69	1,33	2,69	1,34	2,68	1,35	2,67	1,36	2,67	1,37	2,66	1,39	2,66	1,40	3
4	3,60	1,75	3,59	1,77	3,58	1,79	3,57	1,80	3,56	1,82	3,56	1,83	3,55	1,85	3,54	1,86	4
5	4,49	2,19	4,48	2,21	4,48	2,23	4,47	2,25	4,46	2,27	4,45	2,29	4,44	2,31	4,43	2,32	5
6	5,39	2,63	5,38	2,65	5,37	2,68	5,36	2,70	5,35	2,72	5,33	2,75	5,32	2,77	5,31	2,79	6
7	6,29	3,07	6,28	3,10	6,27	3,12	6,25	3,15	6,24	3,18	6,22	3,21	6,21	3,23	6,20	3,26	7
8	7,19	3,51	7,18	3,54	7,16	3,57	7,14	3,60	7,13	3,63	7,11	3,66	7,10	3,69	7,08	3,73	8
9	8,09	3,95	8,07	3,98	8,05	4,02	8,04	4,05	8,02	4,09	8,00	4,12	7,98	4,16	7,97	4,19	9
10	8,99	4,38	8,97	4,42	8,95	4,46	8,93	4,50	8,91	4,54	8,89	4,58	8,87	4,62	8,85	4,66	10
11	9,89	4,82	9,87	4,87	9,84	4,91	9,82	4,95	9,80	4,99	9,78	5,04	9,76	5,08	9,73	5,12	11
12	10,79	5,26	10,76	5,31	10,74	5,35	10,72	5,40	10,69	5,45	10,67	5,49	10,64	5,54	10,62	5,59	12
13	11,68	5,70	11,66	5,75	11,63	5,80	11,61	5,85	11,58	5,90	11,56	5,95	11,53	6,00	11,51	6,05	13
14	12,58	6,14	12,56	6,19	12,53	6,25	12,50	6,30	12,47	6,36	12,45	6,41	12,42	6,47	12,40	6,52	14
15	13,48	6,58	13,45	6,63	13,42	6,69	13,40	6,75	13,37	6,81	13,34	6,87	13,31	6,93	13,28	6,99	15
16	14,38	7,01	14,35	7,08	14,32	7,14	14,29	7,20	14,26	7,26	14,22	7,33	14,19	7,39	14,16	7,45	16
17	15,28	7,45	15,25	7,52	15,21	7,59	15,18	7,65	15,15	7,72	15,11	7,78	15,08	7,85	15,05	7,92	17
18	16,18	7,89	16,14	7,96	16,11	8,03	16,07	8,10	16,04	8,17	16,00	8,24	15,97	8,31	15,93	8,38	18
19	17,08	8,33	17,04	8,40	17,00	8,48	16,97	8,55	16,93	8,63	16,89	8,70	16,85	8,76	16,82	8,85	19
20	17,98	8,77	17,94	8,85	17,90	8,92	17,86	9,00	17,82	9,08	17,78	9,16	17,74	9,24	17,70	9,31	20
21	18,88	9,21	18,83	9,29	18,79	9,37	18,75	9,45	18,71	9,53	18,67	9,62	18,63	9,70	18,59	9,78	21
22	19,77	9,64	19,73	9,73	19,69	9,82	19,65	9,90	19,60	9,99	19,56	10,07	19,51	10,16	19,47	10,24	22
23	20,67	10,08	20,63	10,17	20,58	10,26	20,54	10,35	20,49	10,44	20,45	10,58	20,40	10,62	20,36	10,71	23
24	21,57	10,52	21,52	10,62	21,48	10,71	21,43	10,80	21,38	10,90	21,34	10,99	21,29	11,08	21,24	11,18	24
25	22,47	10,96	22,42	11,06	22,37	11,16	22,33	11,25	22,28	11,35	22,23	11,45	22,18	11,55	22,13	11,64	25
26	23,37	11,40	23,32	11,50	23,27	11,60	23,22	11,70	23,17	11,80	23,12	11,91	23,06	12,01	23,01	12,11	26
27	24,27	11,84	24,22	11,94	24,16	12,05	24,11	12,15	24,06	12,26	24,00	12,36	23,95	12,47	23,89	12,57	27
28	25,17	12,27	25,11	12,39	25,06	12,49	25,00	12,60	24,95	12,71	24,89	12,82	24,84	12,93	24,73	13,04	28
29	26,07	12,71	26,01	12,83	25,95	12,94	25,90	13,05	25,84	13,17	25,78	13,28	25,72	13,39	25,67	13,60	29
30	26,96	13,15	26,91	13,27	26,85	13,39	26,79	13,50	26,73	13,62	26,67	13,74	26,61	13,85	26,55	13,97	30
31	27,86	13,59	27,80	13,71	27,74	13,83	27,68	13,95	27,62	14,07	27,56	14,19	27,50	14,32	27,44	14,43	31
32	28,76	14,03	28,70	14,15	28,64	14,28	28,58	14,40	28,51	14,53	28,45	14,65	28,38	14,78	28,32	14,90	32
33	29,66	14,47	29,60	14,60	29,53	14,73	29,47	14,85	29,40	14,98	29,34	15,11	29,27	15,24	29,21	15,37	33
34	30,56	14,90	30,49	15,04	30,43	15,17	30,36	15,30	30,29	15,44	30,23	15,57	30,16	15,70	30,09	15,83	34
35	31,46	15,34	31,39	15,48	31,32	15,62	31,25	15,75	31,19	15,89	31,12	16,03	31,05	16,16	30,98	16,30	35
36	32,36	15,78	32,29	15,92	32,22	16,06	32,15	16,20	32,08	16,34	32,01	16,48	31,93	16,62	31,86	16,76	36
37	33,26	16,22	33,18	16,37	33,11	16,51	33,04	16,65	32,97	16,80	32,89	16,94	32,82	17,09	32,75	17,23	37
38	34,15	16,66	34,08	16,81	34,01	16,96	33,93	17,10	33,86	17,25	33,78	17,40	33,71	17,55	33,63	17,70	38
39	35,05	17,10	34,98	17,25	34,90	17,40	34,83	17,55	34,75	17,71	34,67	17,85	34,59	18,00	34,52	18,16	39
40	35,95	17,54	35,88	17,69	35,80	17,85	35,72	18,00	35,64	18,16	35,56	18,31	35,49	18,47	35,40	18,62	40
41	36,85	17,97	36,77	18,13	36,69	18,29	36,61	18,45	36,53	18,61	36,45	18,77	36,37	18,93	36,29	19,09	41
42	37,75	18,41	37,67	18,58	37,59	18,74	37,51	18,90	37,42	19,07	37,34	19,23	37,25	19,39	37,17	19,50	42
43	38,65	18,85	38,57	19,02	38,48	19,19	38,40	19,35	38,31	19,52	38,23	19,69	38,14	19,86	38,06	20,02	43
44	39,55	19,29	39,46	19,46	39,38	19,63	39,29	19,80	39,20	19,98	39,12	20,15	39,03	20,32	38,94	20,49	44
45	40,45	19,73	40,36	19,90	40,27	20,08	40,18	20,26	40,10	20,43	40,01	20,61	39,92	20,78	39,83	20,95	45
46	41,35	20,17	41,26	20,35	41,17	20,53	41,08	20,71	40,99	20,88	40,90	21,06	40,80	21,24	40,71	21,42	46
47	42,24	20,60	42,15	20,79	42,06	20,97	41,97	21,16	41,88	21,34	41,78	21,52	41,69	21,70	41,60	21,89	47
48	43,14	21,04	43,05	21,23	42,96	21,42	42,86	21,61	42,77	21,79	42,67	21,98	42,58	22,16	42,48	22,35	48
49	44,04	21,48	43,95	21,67	43,85	21,86	43,76	22,06	43,66	22,25	43,56	22,44	43,46	22,63	43,37	22,82	49
50	44,94	21,92	44,84	22,12	44,75	22,31	44,65	22,51	44,55	22,70	44,45	22,89	44,35	23,09	44,25	23,28	50
51	45,84	22,36	45,74	22,56	45,64	22,76	45,54	22,96	45,44	23,15	45,35	23,35	45,25	23,55	45,14	23,75	51
52	46,74	22,80	46,64	23,00	46,54	23,20	46,44	23,41	46,33	23,61	46,23	23,81	46,14	24,01	46,02	24,21	52
53	47,64	23,23	47,53	23,44	47,43	23,65	47,32	23,86	47,22	24,06	47,12	24,27	47,03	24,47	46,91	24,68	53
54	48,54	23,67	48,43	23,88	48,33	24,10	48,21	24,31	48,12	24,52	48,01	24,73	47,91	24,94	47,79	25,15	54
55	49,43	24,11	49,33	24,33	49,22	24,54	49,11	24,76	49,01	24,97	48,90	25,19	48,79	25,40	48,68	25,61	55
56	50,33	24,55	50,23	24,77	50,12	24,99	50,00	25,21	49,90	25,42	49,78	25,64	49,68	25,86	49,56	26,08	56
57	51,23	24,99	51,12	25,21	51,01	25,43	50,89	25,66	50,79	25,88	50,67	26,10	50,57	26,32	50,45	26,54	57
58	52,13	25,43	52,02	25,65	51,91	25,88	51,78	26,11	51,68	26,33	51,59	26,56	51,45	26,78	51,33	27,01	58
59	53,03	25,86	52,92	26,10	52,80	26,33	52,68	26,56	52,57	26,79	52,45	27,02	52,33	27,25	52,22	27,48	59
60	53,93	26,30	53,81	26,54	53,70	26,77	53,57	27,01	53,46	27,24	53,34	27,47	53,22	27,71	53,10	27,95	60
Distance	Dep. Lat.		Dep. Lat.		Dep. Lat.		Dep. Lat.		Dep. Lat.		Dep. Lat.		Dep. Lat.		Dep. Lat.		Distance
	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.		
	64 Deg.		63 Degrees		62 Degrees		1,88										

TRAVERSE TABLE, 67.

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26 Degrees								27 Degrees								Distance	
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		Distance	
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
61	54,83	26,74	54,71	26,98	54,59	27,22	54,47	27,46	54,35	27,69	54,23	27,93	54,11	28,17	53,98	28,40	61
62	55,73	27,18	55,61	27,42	55,49	27,66	55,37	27,91	55,24	28,15	55,12	28,39	55,00	28,63	54,87	28,87	62
63	56,62	27,62	56,50	27,86	56,38	28,11	56,25	28,36	56,13	28,60	56,02	28,85	55,88	29,09	55,75	29,34	63
64	57,52	28,05	57,40	28,31	57,28	28,56	57,15	28,81	57,03	29,06	56,90	29,30	56,77	29,55	56,64	29,80	64
65	58,42	28,49	58,30	28,75	58,17	29,00	58,04	29,26	57,92	29,51	57,79	29,76	57,66	30,02	57,52	30,27	65
66	59,32	28,93	59,19	29,19	59,07	29,45	58,94	29,71	58,81	29,96	58,68	30,22	58,5	30,48	58,41	30,73	66
67	60,22	29,37	60,09	29,63	59,96	29,89	59,83	30,07	59,70	30,42	59,56	30,68	59,4	30,94	59,29	31,20	67
68	61,12	29,81	60,99	30,07	60,86	30,34	60,72	30,61	60,59	30,87	60,45	31,14	60,32	31,40	60,18	31,67	68
69	62,02	30,24	61,89	30,52	61,75	30,79	61,62	31,06	61,48	31,33	61,34	31,59	61,20	31,86	61,06	32,13	69
70	62,92	30,69	62,78	30,90	62,65	31,23	62,51	31,51	62,37	31,78	62,23	32,06	62,00	32,32	61,95	32,59	70
71	63,81	31,12	63,68	31,40	63,54	31,68	63,40	31,96	63,26	32,23	63,12	32,51	62,98	32,79	62,83	33,06	71
72	64,71	31,56	64,58	31,84	64,44	32,13	64,30	32,41	64,15	32,69	64,01	32,97	63,87	33,25	63,72	33,53	72
73	65,61	32,00	65,47	32,29	65,33	32,57	65,19	32,86	65,04	33,14	64,90	33,43	64,75	33,71	64,60	33,99	73
74	66,51	32,44	66,37	32,73	66,23	33,02	66,08	33,31	65,94	33,60	65,79	33,88	65,64	34,17	65,49	34,46	74
75	67,41	32,88	67,27	33,17	67,12	33,46	66,97	33,76	66,83	34,05	66,68	34,34	66,53	34,63	66,37	34,92	75
76	68,31	33,31	68,17	33,61	68,02	33,91	67,87	34,21	67,72	34,50	67,57	34,80	67,41	35,10	67,25	35,39	76
77	69,21	33,75	69,06	34,05	68,91	34,36	68,77	34,66	68,61	34,96	68,45	35,26	68,30	35,56	68,14	35,86	77
78	70,11	34,19	69,96	34,50	69,81	34,80	69,65	35,11	69,50	35,41	69,34	35,72	69,19	36,02	69,03	36,32	78
79	71,01	34,63	70,86	34,9	70,70	35,25	70,55	35,56	70,39	35,87	70,23	36,17	70,07	36,48	69,91	36,79	79
80	71,90	35,07	71,75	35,38	71,59	35,70	71,44	36,01	71,28	36,32	71,12	36,63	70,96	36,94	70,80	37,25	80
81	72,80	35,51	72,65	35,83	72,49	36,14	72,33	36,46	72,17	36,77	72,01	37,09	71,85	37,40	71,68	37,72	81
82	73,70	35,95	73,54	36,27	73,38	36,59	73,22	36,91	73,06	37,23	72,90	37,55	72,74	37,86	72,57	38,18	82
83	74,60	36,38	74,44	36,71	74,28	37,03	74,12	37,36	73,95	37,68	73,79	38,00	73,62	38,33	73,46	38,65	83
84	75,50	36,82	75,34	37,15	75,17	37,47	75,01	37,81	74,85	38,14	74,68	38,46	74,51	38,79	74,34	39,11	84
85	76,40	37,26	76,24	37,59	76,07	37,93	75,9	38,26	75,74	38,59	75,57	38,92	75,40	39,25	75,23	39,58	85
86	77,30	37,70	77,13	38,04	76,96	38,37	76,80	38,71	76,63	39,04	76,46	39,38	76,28	39,71	76,11	40,05	86
87	78,20	38,14	78,03	38,48	77,86	38,82	77,69	39,16	77,52	39,50	77,35	39,84	77,17	40,17	77,00	40,51	87
88	79,10	38,57	78,93	38,92	78,75	39,26	78,58	39,61	78,41	39,95	78,23	40,29	78,06	40,64	77,88	40,98	88
89	80,00	39,01	79,82	39,36	79,63	39,71	79,48	40,06	79,30	40,41	79,13	40,75	78,94	41,10	78,77	41,44	89
90	80,90	39,45	80,72	39,81	80,54	40,16	80,37	40,51	80,19	40,86	80,01	41,21	79,83	41,56	79,65	41,91	90
91	81,79	39,89	81,62	40,24	81,44	40,60	81,26	40,96	81,08	41,31	80,90	41,67	80,72	42,02	80,53	42,37	91
92	82,69	40,33	82,51	40,70	82,33	41,03	82,15	41,41	81,97	41,77	81,79	42,12	81,61	42,48	81,42	42,84	92
93	83,59	40,77	83,41	41,13	83,23	41,50	83,05	41,86	82,86	42,22	82,68	42,58	82,49	42,94	82,30	43,30	93
94	84,49	41,21	84,31	41,57	84,12	41,94	83,94	42,31	83,75	42,68	83,57	43,04	83,38	43,41	83,19	43,77	94
95	85,39	41,65	85,20	42,02	85,02	42,39	84,85	42,76	84,64	43,13	84,46	43,50	84,27	43,87	84,07	44,24	95
96	86,29	42,08	86,10	42,46	85,91	42,83	85,73	43,21	85,5	43,59	85,35	43,96	85,15	44,33	84,96	44,70	96
97	87,19	42,52	87,00	42,90	86,81	43,28	86,62	43,66	86,43	44,04	86,24	44,41	86,04	44,79	85,84	45,17	97
98	88,08	42,96	87,89	43,33	87,70	43,73	87,52	44,11	87,32	44,49	87,12	44,87	86,93	45,25	86,73	45,63	98
99	88,98	43,40	88,79	43,78	88,60	44,17	88,41	44,56	88,21	44,95	88,01	45,33	87,81	45,72	87,61	46,10	99
100	89,88	43,84	89,69	44,22	89,49	44,62	89,30	45,01	89,10	45,40	88,90	45,79	88,70	46,18	88,50	46,56	100
101	90,78	44,28	90,58	44,67	90,39	45,07	90,19	45,46	89,99	45,85	89,79	46,24	89,59	46,64	89,38	47,03	101
102	91,68	44,71	91,48	45,11	91,28	45,51	91,08	45,91	90,88	46,31	90,68	46,70	90,48	47,10	90,27	47,49	102
103	92,58	45,15	92,38	45,56	92,18	45,96	91,98	46,36	91,77	46,76	91,57	47,16	91,36	47,56	91,15	47,96	103
104	93,48	45,59	93,28	46,00	93,08	46,40	92,87	46,81	92,67	47,22	92,46	47,60	92,25	48,02	92,04	48,43	104
105	94,37	46,03	94,17	46,44	93,97	46,85	93,76	47,26	93,56	47,68	93,35	48,06	93,14	48,49	92,92	48,89	105
106	95,27	46,47	95,07	46,88	94,86	47,30	94,66	47,71	94,45	48,12	94,24	48,54	94,02	48,95	93,81	49,36	106
107	96,17	46,90	95,97	47,32	95,76	47,74	95,55	48,16	95,34	48,59	95,13	48,99	94,91	49,41	94,60	49,82	107
108	97,07	47,34	96,86	47,77	96,65	48,16	96,44	48,61	96,23	49,00	96,01	49,45	95,80	49,87	95,58	50,29	108
109	97,97	47,77	97,76	48,21	97,55	48,63	97,34	49,06	97,12	49,46	96,90	49,91	96,68	50,33	96,46	50,76	109
110	98,87	48,22	98,66	48,65	98,44	49,08	98,22	49,51	98,0	49,94	97,79	50,37	97,57	50,79	97,35	51,22	110
111	99,77	48,65	99,55	49,09	99,34	49,55	99,12	49,96	98,91	50,39	98,68	50,82	98,46	51,26	98,23	51,68	111
112	100,67	49,10	100,45	49,54	100,22	49,97	100,0	50,41	99,80	50,85	99,57	51,28	99,35	51,72	99,12	52,15	112
113	101,57	49,54	101,33	49,98	101,09	50,41	100,8	50,86	100,7	51,30	100,4	51,74	100,2	52,18	100,0	52,62	113
114	102,47	49,97	102,23	50,42	101,9	50,87	101,8	51,31	101,6	51,76	101,5	52,20	101,3	52,64	100,9	53,08	114
115	103,37	50,41	103,1	50,86	102,8	51,31	102,7	51,76	102,5	52,21	102,2	52,66	102,0	53,10	101,8	53,55	115
116	104,27	50,85	104,0	51,30	103,7	51,76	103,6	52,21	103,4	52,66	103,1	53,11	102,9	53,57	102,7	54,01	116
117	105,17	51,28	104,9	51,75	104,6	52,20	104,5	52,66	104,2	53,12	104,0	53,57	103,8	54,03	103,5	54,49	117
118	106,07	51,72	105,8	52,19	105,5	52,65	105,4	53,11	105,0	53,57	104,9	54,03	104,7	54,49	104,4	54,95	118
119	106,97	52,16	106,7	52,63	106,4	53,10	106,3	53,56	105,9								

TRAVERSE TABLE, 67.

Distance	28 Degrees								53	29 Degrees								55	Distance
	0 Min.		15 Min.		30 Min.		45 Min.			0 Min.		15 Min.		30 Min.		45 Min.			
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
	0.88	0.47	0.88	0.47	0.88	0.48	0.88	0.48		0.88	0.49	0.87	0.49	0.87	0.49	0.87	0.50		
1	0.88	0.47	0.88	0.47	0.88	0.48	0.88	0.48	0.88	0.49	0.87	0.49	0.87	0.49	0.87	0.50	1		
2	1.77	0.94	1.76	0.95	1.76	0.95	1.75	0.96	1.75	0.97	1.75	1.00	1.74	0.99	1.74	0.99	2		
3	2.65	1.41	2.64	1.42	2.64	1.43	2.63	1.44	2.62	1.46	2.62	1.47	2.61	1.48	2.61	1.49	3		
4	3.53	1.88	3.52	1.89	3.52	1.91	3.51	1.92	3.50	1.94	3.49	1.96	3.48	1.97	3.47	1.99	4		
5	4.42	2.35	4.40	2.37	4.39	2.39	4.38	2.41	4.37	2.43	4.36	2.45	4.35	2.46	4.34	2.48	5		
6	5.30	2.82	5.29	2.84	5.27	2.86	5.26	2.89	5.25	2.91	5.25	2.93	5.22	2.96	5.21	2.98	6		
7	6.18	3.29	6.17	3.31	6.15	3.34	6.14	3.37	6.12	3.40	6.11	3.42	6.09	3.45	6.08	3.47	7		
8	7.06	3.76	7.05	3.79	7.03	3.82	7.01	3.85	6.99	3.88	6.98	3.91	6.96	3.94	6.95	3.97	8		
9	7.95	4.23	7.93	4.27	7.91	4.29	7.89	4.33	7.87	4.37	7.85	4.40	7.83	4.43	7.81	4.47	9		
10	8.83	4.70	8.81	4.73	8.79	4.77	8.77	4.81	8.75	4.85	8.73	4.89	8.70	4.92	8.68	4.96	10		
11	9.71	5.16	9.69	5.21	9.67	5.25	9.64	5.29	9.62	5.33	9.60	5.38	9.57	5.42	9.55	5.46	11		
12	10.60	5.63	10.57	5.68	10.55	5.73	10.52	5.77	10.50	5.82	10.47	5.86	10.44	5.91	10.42	5.96	12		
13	11.48	6.10	11.45	6.15	11.42	6.20	11.40	6.25	11.37	6.30	11.34	6.35	11.31	6.40	11.29	6.45	13		
14	12.36	6.57	12.33	6.63	12.30	6.68	12.28	6.73	12.25	6.79	12.22	6.84	12.18	6.89	12.15	6.95	14		
15	13.24	7.04	13.21	7.10	13.18	7.16	13.15	7.22	13.12	7.27	13.09	7.33	13.05	7.39	13.02	7.44	15		
16	14.13	7.51	14.10	7.57	14.06	7.63	14.03	7.70	14.00	7.76	13.96	7.82	13.92	7.88	13.89	7.94	16		
17	15.01	7.98	14.98	8.05	14.94	8.11	14.91	8.18	14.87	8.24	14.84	8.31	14.79	8.37	14.86	8.44	17		
18	15.89	8.45	15.86	8.52	15.82	8.59	15.79	8.66	15.75	8.73	15.71	8.80	15.66	8.86	15.63	8.93	18		
19	16.78	8.92	16.74	8.99	16.70	9.07	16.66	9.14	16.62	9.21	16.58	9.29	16.53	9.35	16.49	9.43	19		
20	17.66	9.39	17.62	9.46	17.58	9.54	17.54	9.62	17.49	9.70	17.45	9.77	17.41	9.85	17.36	9.92	20		
21	18.54	9.86	18.50	9.94	18.46	10.02	18.41	10.10	18.37	10.18	18.32	10.26	18.28	10.34	18.23	10.42	21		
22	19.43	10.33	19.38	10.41	19.33	10.50	19.29	10.58	19.24	10.67	19.20	10.75	19.15	10.83	19.10	10.92	22		
23	20.31	10.80	20.26	10.89	20.21	10.97	20.17	11.06	20.12	11.15	20.07	11.24	20.02	11.32	19.97	11.41	23		
24	21.19	11.27	21.14	11.36	21.09	11.45	21.04	11.54	20.99	11.64	20.94	11.73	20.89	11.82	20.84	11.91	24		
25	22.07	11.74	22.02	11.83	21.97	11.93	21.92	12.03	21.87	12.12	21.82	12.22	21.76	12.31	21.70	12.40	25		
26	22.96	12.20	22.90	12.30	22.85	12.41	22.79	12.51	22.74	12.61	22.69	12.71	22.63	12.81	22.57	12.60	26		
27	23.84	12.67	23.79	12.78	23.73	12.88	23.67	12.99	23.62	13.09	23.57	13.20	23.50	13.29	23.44	13.40	27		
28	24.72	13.14	24.67	13.25	24.61	13.36	24.55	13.47	24.49	13.58	24.43	13.68	24.37	13.78	24.31	13.89	28		
29	25.61	13.61	25.55	13.72	25.49	13.83	25.43	13.95	25.37	14.06	25.31	14.17	25.24	14.28	25.18	14.39	29		
30	26.49	14.08	26.43	14.20	26.37	14.32	26.30	14.43	26.24	14.54	26.18	14.66	26.11	14.77	26.05	14.89	30		
31	27.37	14.55	27.31	14.67	27.24	14.79	27.18	14.91	27.11	15.03	27.05	15.15	26.98	15.27	26.91	15.38	31		
32	28.26	15.02	28.19	15.14	28.12	15.27	28.06	15.39	27.99	15.51	27.92	15.64	27.85	15.76	27.78	15.88	32		
33	29.14	15.49	29.07	15.62	28.99	15.75	28.93	15.87	28.86	16.00	28.80	16.13	28.72	16.25	28.65	16.38	33		
34	30.02	15.96	29.95	16.09	29.88	16.22	29.81	16.35	29.74	16.48	29.67	16.61	29.59	16.74	29.52	16.87	34		
35	30.90	16.43	30.83	16.57	30.76	16.70	30.69	16.84	30.61	16.96	30.54	17.10	30.46	17.23	30.39	17.37	35		
36	31.79	16.90	31.71	17.04	31.64	17.18	31.56	17.32	31.49	17.45	31.42	17.59	31.33	17.73	31.25	17.86	36		
37	32.67	17.37	32.59	17.51	32.52	17.65	32.44	17.80	32.36	17.94	32.29	18.08	32.20	18.22	32.12	18.36	37		
38	33.55	17.84	33.48	17.98	33.40	18.13	33.32	18.28	33.24	18.42	33.16	18.57	33.07	18.71	32.99	18.84	38		
39	34.44	18.31	34.36	18.46	34.28	18.61	34.20	18.76	34.11	18.90	34.03	19.06	33.94	19.20	33.86	19.35	39		
40	35.32	18.78	35.24	18.93	35.15	19.09	35.07	19.24	35.00	19.39	34.90	19.54	34.81	19.70	34.73	19.85	40		
41	36.20	19.25	36.12	19.41	36.03	19.56	35.95	19.72	35.85	19.88	35.77	20.03	35.68	20.19	35.60	20.35	41		
42	37.08	19.72	37.00	19.88	36.91	20.01	36.82	20.20	36.73	20.36	36.65	20.52	36.55	20.68	36.46	20.85	42		
43	37.97	20.19	37.88	20.35	37.79	20.52	37.70	20.68	37.60	20.85	37.52	21.01	37.42	21.17	37.33	21.34	43		
44	38.85	20.66	38.76	20.83	38.67	20.99	38.58	21.16	38.48	21.33	38.39	21.50	38.29	21.67	38.20	21.84	44		
45	39.73	21.12	39.64	21.30	39.55	21.47	39.45	21.65	39.35	21.82	39.27	21.99	39.16	22.16	39.07	22.33	45		
46	40.61	21.59	40.52	21.77	40.43	21.93	40.33	22.13	40.23	22.30	40.14	22.48	40.03	22.65	39.94	22.83	46		
47	41.50	22.06	41.40	22.24	41.31	22.43	41.21	22.61	41.10	22.80	41.01	22.97	40.90	23.14	40.80	23.32	47		
48	42.38	22.53	42.28	22.72	42.19	22.90	42.09	23.09	41.98	23.28	41.88	23.46	41.77	23.63	41.67	23.82	48		
49	43.26	23.00	43.17	23.19	43.08	23.38	42.98	23.57	42.85	23.77	42.76	23.95	42.64	24.13	42.54	24.31	49		
50	44.15	23.47	44.05	23.67	43.94	23.86	43.84	24.05	43.73	24.24	43.63	24.43	43.52	24.62	43.41	24.81	50		
51	45.03	23.94	44.93	24.14	44.84	24.34	44.71	24.53	44.61	24.73	44.50	24.93	44.39	25.11	44.28	25.31	51		
52	45.91	24.41	45.81	24.61	45.70	24.81	45.59	25.01	45.48	25.61	45.37	25.42	45.26	25.61	45.15	25.80	52		
53	46.80	24.88	46.69	25.09	46.58	25.29	46.47	25.49	46.36	25.70	46.24	25.91	46.13	26.10	46.01	26.30	53		
54	47.68	25.35	47.57	25.56	47.46	25.77	47.35	25.97	47.23	26.18	47.12	26.40	47.00	26.59	46.88	26.80	54		
55	48.56	25.82	48.45	26.03	48.34	26.24	48.22	26.46	48.11	26.67	47.99	26.89	47.87	27.08	47.75	27.29	55		
56	49.45	26.29	49.33	26.50	49.22	26.72	49.10	26.94	48.98	27.15	48.86	27.37	48.74	27.57	48.62	27.79	56		
57	50.33	26.76	50.21	26.97	50.09	27.20	49.98	27.42	49.86	27.64	49.74	27.86	49.61	28.07	49.49	28.28	57		
58	51.21	27.23	51.09	27															

TRAVERSE TABLE, 67.

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28 Degrees																29 Degrees																Distance
53																55																
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.										
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.									
61	53,86	28,64	53,73	28,87	53,61	29,11	53,48	29,34	53,35	29,57	53,22	29,81	53,09	30,04	52,96	30,27	61	53,35	29,57	53,22	29,81	53,09	30,04	52,96	30,27	61						
62	53,74	29,11	53,62	29,35	53,49	29,58	53,36	29,82	53,23	30,06	53,10	30,29	52,96	30,53	52,83	30,77	62	54,23	30,06	54,10	30,29	53,96	30,53	53,83	30,77	62						
63	53,63	29,58	53,50	29,82	53,37	30,06	53,24	30,30	53,10	30,54	52,97	30,78	52,83	31,02	52,70	31,26	63	54,10	30,54	54,00	30,78	53,83	31,02	53,70	31,26	63						
64	53,51	30,04	53,38	30,29	53,25	30,54	53,11	30,78	52,98	31,03	52,84	31,27	52,70	31,51	52,56	31,76	64	54,00	30,78	53,87	30,78	53,73	31,02	53,60	31,26	64						
65	53,39	30,51	53,26	30,76	53,12	31,02	52,99	31,26	52,85	31,51	52,72	31,76	52,57	32,01	52,43	32,25	65	53,51	31,03	53,37	31,27	53,23	31,51	53,09	31,76	65						
66	53,28	30,98	53,14	31,24	52,99	31,41	52,87	31,75	52,73	32,00	52,58	32,25	52,44	32,50	52,30	32,75	66	53,40	31,51	53,26	31,76	53,12	31,41	52,99	31,76	66						
67	53,16	31,45	53,02	31,70	52,87	31,97	52,74	32,23	52,60	32,48	52,46	32,74	52,31	32,99	52,17	33,25	67	53,30	32,00	53,16	31,97	53,02	31,70	52,87	31,97	67						
68	53,04	31,92	52,90	32,18	52,75	32,45	52,62	32,71	52,48	32,97	52,33	33,23	52,18	33,48	52,04	33,74	68	53,20	32,48	53,06	32,25	52,92	32,45	52,78	32,75	68						
69	52,52	32,39	52,38	32,66	52,23	32,92	52,09	33,19	51,96	33,46	51,82	33,72	51,67	33,97	51,52	34,24	69	53,10	32,97	53,00	32,74	52,59	32,71	52,46	32,75	69						
70	52,40	32,86	52,26	33,13	52,11	33,41	51,97	33,67	51,82	33,94	51,68	34,20	51,53	34,41	51,38	34,74	70	53,00	33,46	52,90	33,23	52,75	33,01	52,50	33,25	70						
71	52,28	33,33	52,14	33,61	52,00	33,88	51,85	34,15	51,70	34,44	51,56	34,69	51,41	34,96	51,26	35,23	71	52,50	33,94	52,40	33,72	52,25	33,51	52,00	33,75	71						
72	52,16	33,80	52,02	34,08	51,88	34,36	51,65	34,63	51,50	34,91	51,32	35,18	51,17	35,45	51,02	35,73	72	52,40	34,44	52,30	34,22	52,15	34,00	51,75	34,50	72						
73	52,04	34,27	51,90	34,55	51,76	34,83	51,53	35,11	51,38	35,39	51,20	35,67	51,05	35,95	50,90	36,22	73	52,30	34,91	52,20	34,00	52,05	33,80	51,80	35,00	73						
74	51,52	34,74	51,38	35,02	51,24	35,31	51,01	35,59	50,88	35,88	50,69	36,16	50,54	36,44	50,39	36,72	74	52,20	35,39	52,10	34,00	51,95	33,60	51,65	35,20	74						
75	51,40	35,21	51,26	35,50	51,12	35,79	50,99	36,03	50,80	36,36	50,61	36,65	50,46	36,93	50,31	37,22	75	52,10	35,88	52,00	34,00	51,85	33,40	51,60	35,40	75						
76	51,28	35,68	51,14	35,97	51,00	36,26	50,85	36,56	50,70	36,85	50,51	37,14	50,36	37,42	50,21	37,71	76	52,00	36,36	51,90	34,00	51,75	33,20	51,55	35,60	76						
77	51,16	36,15	51,02	36,44	50,88	36,74	50,69	37,04	50,54	37,33	50,35	37,63	50,20	37,91	50,05	38,21	77	51,90	36,85	51,80	34,00	51,65	33,00	51,45	35,80	77						
78	51,04	36,62	50,90	36,92	50,76	37,22	50,61	37,52	50,46	37,82	50,27	38,11	50,12	38,41	49,97	38,70	78	51,80	37,33	51,70	34,00	51,55	32,80	51,40	36,00	78						
79	50,92	37,09	50,78	37,39	50,63	37,69	50,50	37,99	50,35	38,30	50,16	38,60	50,01	38,90	49,86	39,20	79	51,70	37,82	51,60	34,00	51,45	32,60	51,35	36,20	79						
80	50,80	37,56	50,66	37,87	50,52	38,11	50,37	38,48	50,22	38,78	50,03	39,09	49,88	39,39	49,70	39,70	80	51,60	38,30	51,50	34,00	51,35	32,40	51,25	36,40	80						
81	50,68	38,03	50,54	38,34	50,40	38,65	50,25	38,96	50,10	39,27	49,91	39,58	49,76	40,07	49,61	40,20	81	51,50	38,78	51,40	34,00	51,25	32,20	51,15	36,60	81						
82	50,56	38,50	50,42	38,81	50,28	39,13	50,13	39,44	50,00	39,75	49,80	40,07	49,92	40,38	49,77	40,69	82	51,40	39,27	51,30	34,00	51,05	32,00	51,00	36,80	82						
83	50,44	38,97	50,30	39,29	50,15	39,61	50,00	39,92	49,85	40,24	49,70	40,56	49,55	40,87	49,72	41,19	83	51,30	39,75	51,20	34,00	50,95	31,80	50,90	37,00	83						
84	50,32	39,44	50,18	39,70	50,03	40,08	49,88	40,40	49,73	40,72	49,58	41,04	49,43	41,36	49,28	41,68	84	51,20	40,24	51,10	34,00	50,85	31,60	50,80	37,20	84						
85	50,20	39,91	50,06	40,17	49,91	40,43	49,76	40,88	49,61	41,21	49,47	41,53	49,32	41,85	49,17	42,18	85	51,10	40,72	51,00	34,00	50,75	31,40	50,70	37,40	85						
86	50,08	40,38	49,94	40,64	49,79	40,90	41,37	41,37	41,37	41,70	41,56	42,02	41,41	42,34	41,26	42,67	86	51,00	41,21	50,90	34,00	50,65	31,20	50,60	37,60	86						
87	50,00	40,84	49,86	41,10	49,62	41,51	41,85	42,18	41,99	42,51	41,85	43,00	41,70	43,33	41,55	43,67	87	50,90	41,70	50,80	34,00	50,55	31,00	50,50	37,80	87						
88	49,52	41,31	49,48	41,65	49,34	41,99	42,33	42,67	42,13	42,67	42,51	43,00	42,35	43,33	42,17	43,67	88	50,80	42,18	50,70	34,00	50,45	30,80	50,40	38,00	88						
89	49,40	41,78	49,36	42,12	49,22	42,47	42,81	43,15	42,61	43,15	42,99	43,49	42,83	43,82	42,67	44,16	89	50,70	42,67	50,60	34,00	50,35	30,60	50,30	38,20	89						
90	49,28	42,25	49,24	42,60	49,10	42,94	43,29	43,63	43,09	43,63	43,47	43,97	43,31	44,32	43,15	44,66	90	50,60	43,15	50,50	34,00	50,25	30,40	50,20	38,40	90						
91	49,16	42,72	49,12	43,07	49,00	43,42	43,77	44,12	43,58	44,12	43,96	44,46	43,80	44,81	43,65	45,16	91	50,50	43,63	50,40	34,00	50,15	30,20	50,10	38,60	91						
92	49,04	43,19	49,00	43,55	48,88	43,90	44,25	44,60	44,06	44,60	44,44	44,95	44,29	45,30	44,13	45,65	92	50,40	44,12	50,30	34,00	50,05	30,00	50,00	38,80	92						
93	48,92	43,66	48,88	44,02	48,76	44,38	44,73	45,09	44,55	45,09	44,93	45,44	44,77	45,79	44,61	46,15	93	50,30	44,60	50,20	34,00	49,95	29,80	49,90	39,00	93						
94	48,80	44,13	48,76	44,49	48,64	44,85	45,21	45,57	45,03	45,57	45,41	45,98	45,31	46,38	45,15	46,64	94	50,20	45,09	50,10	34,00	49,85	29,60	49,80	39,20	94						
95	48,68	44,60	48,64	44,96	48,52	45,33	45,69	46,06	45,52	46,06	45,86	46,54	45,69	47,00	45,53	47,36	95	50,10	45,57	50,00	34,00	49,75	29,40	49,70	39,40	95						
96	48,56	45,07	48,52	45,44	48,40	45,81	46,18	46,54	46,00	46,54	46,38	47,00	46,14	47,42	46,07	47,71	96	50,00	46,06	49,90	34,00	49,65	29,20	49,60	39,60	96						
97	48,44	45,54	48,40	45,91	48,28	46,28	46,66	47,04	46,50	47,04	46,88	47,46	47,02	47,84	46,67	48,13	97	49,90	46,54	49,80	34,00	49,55	29,00	49,50	39,80	97						
98	48,32	46,00	48,28	46,38	48,16	46,78	47,14	47,52	47,00	47,52	47,36	47,94	47,50	48,36	47,19	48,43	98	49,80	47,04	49,70	34,00	49,45	28,80	49,40	40,00	98						
99	48,20	46,47	48,16	46,86	48,04	47,24	47,62	48,00	47,46	48,00	47,84	48,42	47,98	48,84	47,61																	

Distance	30 Degrees								31 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	0,87	0,50	0,86	0,50	0,86	0,51	0,86	0,51	0,86	0,51	0,85	0,52	0,85	0,52	0,85	0,53	
1	0,87	0,50	0,86	0,50	0,86	0,51	0,86	0,51	0,86	0,51	0,85	0,52	0,85	0,52	0,85	0,53	1
2	1,73	1,00	1,73	1,00	1,72	1,01	1,72	1,02	1,71	1,03	1,71	1,04	1,70	1,04	1,70	1,05	2
3	2,60	1,50	2,59	1,51	2,58	1,52	2,58	1,53	2,57	1,54	2,56	1,56	2,56	1,57	2,55	1,58	3
4	3,46	2,00	3,45	2,01	3,45	2,03	3,44	2,04	3,43	2,06	3,42	2,07	3,41	2,09	3,40	2,10	4
5	4,33	2,50	4,32	2,52	4,31	2,54	4,28	2,56	4,29	2,57	4,27	2,59	4,26	2,61	4,25	2,62	5
6	5,20	3,00	5,18	3,02	5,17	3,04	5,16	3,07	5,14	3,09	5,13	3,11	5,12	3,13	5,10	3,16	6
7	6,06	3,50	6,05	3,53	6,03	3,55	6,02	3,58	6,00	3,60	5,98	3,63	5,97	3,66	5,95	3,68	7
8	6,9	4,00	6,91	4,03	6,89	4,06	6,88	4,09	6,86	4,12	6,84	4,15	6,82	4,18	6,80	4,21	8
9	7,74	4,50	7,77	4,53	7,75	4,57	7,73	4,60	7,71	4,63	7,69	4,67	7,67	4,70	7,65	4,74	9
10	8,66	5,00	8,64	5,04	8,62	5,07	8,59	5,11	8,57	5,15	8,55	5,19	8,53	5,22	8,50	5,26	10
11	9,53	5,50	9,50	5,54	9,48	5,58	9,45	5,62	9,43	5,66	9,40	5,71	9,38	5,75	9,35	5,79	11
12	10,39	6,00	10,35	6,04	10,34	6,09	10,31	6,13	10,29	6,18	10,26	6,22	10,23	6,27	10,20	6,31	12
13	11,28	6,50	11,23	6,55	11,20	6,60	11,17	6,65	11,14	6,6	11,11	6,74	11,08	6,79	11,05	6,84	13
14	12,12	7,00	12,09	7,05	12,06	7,10	12,03	7,16	12,00	7,21	11,97	7,26	11,94	7,32	11,90	7,37	14
15	12,99	7,50	12,96	7,56	12,93	7,61	12,89	7,67	12,86	7,72	12,82	7,78	12,79	7,84	12,75	7,89	15
16	13,86	8,00	13,82	8,06	13,79	8,12	13,75	8,18	13,71	8,24	13,68	8,30	13,64	8,36	13,60	8,42	16
17	14,72	8,50	14,69	8,56	14,68	8,63	14,61	8,69	14,57	8,75	14,53	8,82	14,50	8,88	14,45	8,94	17
18	15,59	9,00	15,55	9,07	15,51	9,1	15,47	9,20	15,43	9,27	15,39	9,34	15,35	9,40	15,30	9,47	18
19	16,45	9,50	16,41	9,57	16,37	9,65	16,33	9,71	16,28	9,78	16,24	9,86	16,20	9,93	16,15	10,00	19
20	17,32	10,00	17,28	10,07	17,23	10,15	17,19	10,23	17,14	10,30	17,10	10,37	17,05	10,45	17,01	10,52	20
21	18,19	10,50	18,1	10,58	18,09	10,66	18,05	10,74	18,0	10,82	17,95	10,89	17,91	10,97	17,86	11,05	21
22	19,05	11,00	19,00	11,08	18,96	11,17	18,91	11,25	18,86	11,33	18,81	11,41	18,76	11,50	18,71	11,58	22
23	19,92	11,50	19,87	11,59	19,82	11,67	19,76	11,76	19,71	11,85	19,66	11,93	19,61	12,02	19,56	12,10	23
24	20,78	12,00	20,7	12,09	20,68	12,18	20,62	12,27	20,57	12,36	20,52	12,45	20,46	12,54	20,41	12,63	24
25	21,65	12,50	21,6	12,59	21,54	12,69	21,4	12,78	21,43	12,88	21,37	12,97	21,32	13,06	21,26	13,15	25
26	22,52	13,00	22,46	13,10	22,40	13,20	22,34	13,29	22,28	13,39	22,23	13,49	22,17	13,59	22,11	13,68	26
27	23,38	13,50	23,32	13,60	23,27	13,71	23,20	13,80	23,14	13,91	23,08	14,01	23,02	14,11	22,96	14,21	27
28	24,25	14,00	24,19	14,11	24,1	14,21	24,06	14,31	24,00	14,42	23,94	14,53	23,88	14,63	23,8	14,73	28
29	25,11	14,50	25,05	14,61	24,99	14,7	24,92	14,82	24,86	14,94	24,79	15,05	24,73	15,16	24,66	15,26	29
30	25,98	15,00	25,91	15,11	25,85	15,21	25,73	15,34	25,71	15,45	25,65	15,56	25,58	15,67	25,51	15,79	30
31	26,85	15,50	26,78	15,61	26,71	15,73	26,64	15,85	26,57	15,97	26,50	16,0	26,43	16,20	26,36	16,31	31
32	27,71	16,00	27,64	16,12	27,57	16,24	27,50	16,36	27,43	16,48	27,36	16,60	27,28	16,72	27,21	16,84	32
33	28,58	16,50	28,51	16,62	28,43	16,75	28,36	16,87	28,29	17,00	28,21	17,12	28,14	17,24	28,06	17,36	33
34	29,44	17,00	29,37	17,13	29,30	17,26	29,22	17,38	29,14	17,51	29,07	17,64	28,99	17,77	28,91	17,89	34
35	30,31	17,50	30,23	17,63	30,16	17,77	30,08	17,89	30,00	18,03	29,92	18,16	29,84	18,20	29,76	18,41	35
36	31,18	18,00	31,10	18,14	31,02	18,27	30,94	18,40	30,86	18,54	30,78	18,68	30,70	18,81	30,61	18,94	36
37	32,04	18,50	31,96	18,64	31,88	18,78	31,79	18,92	31,71	19,06	31,63	19,20	31,55	19,34	31,46	19,57	37
38	32,91	19,00	32,83	19,14	32,74	19,29	32,65	19,43	32,57	19,57	32,49	19,71	32,40	19,86	32,31	19,99	38
39	33,77	19,50	33,69	19,65	33,60	19,80	33,51	19,94	33,43	20,09	33,44	20,23	33,24	20,38	33,16	20,51	39
40	34,64	20,00	34,55	20,15	34,46	20,30	34,3	20,45	34,29	20,60	34,20	20,75	34,11	20,90	34,01	21,05	40
41	35,51	20,50	35,42	20,65	35,33	20,81	35,23	20,96	35,14	21,12	35,05	21,27	34,96	21,42	34,86	21,57	41
42	36,37	21,00	36,28	21,16	36,19	21,32	36,09	21,47	36,00	21,63	35,92	21,79	35,81	21,95	35,71	22,10	42
43	37,24	21,50	37,15	21,66	37,05	21,83	36,95	21,98	36,86	22,15	36,76	22,31	36,66	22,47	36,56	22,63	43
44	38,10	22,00	38,01	22,17	37,91	22,33	37,81	22,48	37,71	22,66	37,62	22,83	37,52	22,99	37,41	23,15	44
45	38,97	22,50	38,87	22,67	38,77	22,84	38,67	22,99	38,57	23,18	38,47	23,35	38,37	23,51	38,26	23,68	45
46	39,84	23,00	39,74	23,17	39,64	23,35	39,53	23,50	39,43	23,69	39,33	23,86	39,22	24,04	39,11	24,20	46
47	40,70	23,50	40,60	23,68	40,50	23,86	40,39	24,01	40,29	24,21	40,18	24,38	40,08	24,56	39,96	24,73	47
48	41,57	24,00	41,47	24,18	41,36	24,36	41,25	24,52	41,14	24,72	41,04	24,90	40,93	25,08	40,81	25,26	48
49	42,43	24,50	42,33	24,69	42,22	24,86	42,11	25,03	42,00	25,24	41,89	25,42	41,78	25,61	41,66	25,79	49
50	43,30	25,00	43,19	25,19	43,08	25,36	42,97	25,56	42,86	25,75	42,75	25,94	42,64	26,12	42,52	26,31	50
51	44,16	25,50	44,06	25,69	43,94	25,88	43,82	26,08	43,72	26,27	43,60	26,46	43,48	26,65	43,37	26,84	51
52	45,03	26,00	44,92	26,20	44,8	26,39	44,69	26,59	44,57	26,77	44,46	26,98	44,34	27,17	44,22	27,36	52
53	45,90	26,50	45,78	26,70	45,67	26,90	45,55	27,10	45,45	27,29	45,33	27,50	45,19	27,69	45,07	27,89	53
54	46,76	27,00	46,65	27,20	46,53	27,41	46,41	27,61	46,29	27,80	46,17	28,01	46,04	28,22	45,92	28,41	54
55	47,63	27,50	47,51	27,71	47,39	27,92	47,27	28,12	47,14	28,32	47,02	28,53	46,90	28,74	46,77	28,94	55
56	48,50	28,00	48,38	28,21	48,25	28,42	48,11	28,63	48,00	28,85	47,88	29,06	48,60	29,26	47,62	29,47	56
57	49,36	28,50	49,2	28,71	49,12	28,93	48,98	29,14	48,86	29,35	48,73	29,56	48,60	29,79	48,47	30,00	57
58	50,23	29,00	50,10	29,22	49,98	29,44	49,84	29,65	49,71	29,86	49,59	30,06	49,46	30,31	49,32	30,52	58
59	51,10	29,50	50,97	29,72	50,84	29,95	50,70	30,16	50,57	30,38	50,44	30,61	50,31	30,83	50,17	31,04	59
60	51,96	30,00	51,83	30,23	51,70	30,46	51,56	30,68	51,43	30,9	51,29	31,13	51,16	31,35	51,01	31,57	60
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.				

TRAVERSE TABLE, 67.

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30 Degrees												31 Degrees												Distance							
58												60																			
0 Min.				15 Min.				30 Min.				45 Min.				0 Min.				15 Min.					30 Min.				45 Min.		
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
61	52,83	30,50	52,69	30,73	52,56	30,96	52,42	31,19	52,29	31,42	52,15	31,64	52,01	31,87	51,87	32,10	51,73	32,33	51,59	32,56	51,45	33,19	51,31	33,42	51,17	33,65	51,03	33,88	50,89		
62	52,69	31,00	53,56	31,23	53,42	31,47	53,28	31,70	53,14	31,93	53,00	32,16	52,86	32,40	52,72	32,62	52,58	32,85	52,44	33,08	52,30	33,31	52,16	33,54	52,02	33,77	51,88	34,00	51,74		
63	52,56	31,50	54,42	31,74	54,28	31,98	54,14	32,21	54,00	32,45	53,86	32,68	53,72	32,92	53,57	33,15	53,43	33,39	53,28	33,62	53,14	33,85	52,58	34,10	52,44	34,37	52,30	34,59	52,16		
64	52,43	32,00	55,29	32,24	55,15	32,48	55,00	32,72	54,86	32,96	54,71	33,20	54,57	33,44	54,42	33,68	54,28	33,92	54,14	34,16	53,99	34,40	53,85	34,64	53,70	34,91	53,55	35,17	53,41		
65	52,29	32,50	56,15	32,75	56,01	32,99	55,86	33,23	55,71	33,48	55,57	33,72	55,42	33,96	55,27	34,20	55,13	34,44	54,99	34,68	54,85	34,92	54,71	35,16	54,56	35,41	54,31	35,56	54,17		
66	52,16	33,00	57,01	33,25	56,87	33,50	56,72	33,74	56,57	33,99	56,42	34,24	56,28	34,49	56,12	34,73	55,99	34,97	55,85	35,21	55,71	35,45	55,57	35,69	55,42	35,94	55,27	36,16	55,03		
67	52,02	33,50	57,88	33,75	57,73	34,01	57,58	34,25	57,43	34,51	57,28	34,76	57,13	35,01	56,97	35,25	56,83	35,49	56,68	35,73	56,54	35,97	56,40	36,21	56,22	36,47	56,03	36,64	55,79		
68	51,89	34,00	58,74	34,26	58,59	34,52	58,44	34,76	58,29	35,02	58,13	35,28	57,99	35,53	57,82	35,78	57,67	36,02	57,52	36,26	57,37	36,50	57,23	36,74	57,04	36,99	56,79	37,00	56,55		
69	51,76	34,50	59,61	34,76	59,46	35,02	59,30	35,28	59,14	35,54	58,99	35,80	58,83	36,06	58,67	36,31	58,52	36,55	58,37	36,79	58,22	37,02	58,08	37,26	57,89	37,51	57,65	37,80	57,45		
70	51,62	35,00	60,47	35,26	60,31	35,53	60,16	35,79	60,00	36,05	59,84	36,31	59,68	36,57	59,52	36,83	59,37	37,07	59,22	37,31	59,07	37,55	58,92	37,79	58,73	38,01	58,57	38,26	58,42		
71	51,49	35,50	61,33	35,77	61,18	36,04	61,02	36,30	60,86	36,57	60,70	36,83	60,54	37,09	60,37	37,36	60,22	37,60	60,07	37,84	59,91	38,08	59,76	38,36	59,61	38,58	59,34	38,61	59,10		
72	51,35	36,00	62,20	36,27	62,04	36,54	61,88	36,81	61,72	37,08	61,55	37,35	61,39	37,62	61,22	37,89	61,07	38,13	60,91	38,39	60,76	38,65	60,60	38,91	60,45	39,17	60,21	39,22	60,00		
73	51,22	36,50	63,06	36,79	62,90	37,05	62,74	37,32	62,57	37,60	62,41	37,87	62,24	38,14	62,07	38,41	61,91	38,67	61,75	38,93	61,59	39,19	61,43	39,45	61,28	39,69	61,02	39,74	60,87		
74	51,09	37,00	63,92	37,28	63,76	37,56	63,59	37,83	63,42	38,11	63,25	38,39	63,10	38,67	62,92	38,94	62,76	39,19	62,60	39,45	62,44	39,71	62,28	39,97	62,10	40,00	61,84	40,00	61,69		
75	50,95	37,50	64,79	37,78	64,62	38,07	64,45	38,34	64,28	38,63	64,12	38,91	63,95	39,19	63,77	39,46	63,60	39,71	63,43	39,99	63,27	40,25	63,09	40,47	62,81	40,69	62,63	40,81	62,52		
76	50,82	38,00	65,65	38,29	65,49	38,58	65,31	38,86	65,13	39,14	64,97	39,43	64,82	39,71	64,62	39,99	64,45	40,25	64,28	40,51	64,12	40,77	63,95	41,03	63,77	41,25	63,59	41,47	63,41		
77	50,68	38,50	66,52	38,79	66,35	39,08	66,17	39,37	65,99	39,66	65,83	39,95	65,66	40,23	65,47	40,52	65,30	40,77	65,13	41,03	64,97	41,29	64,82	41,55	64,64	41,87	64,46	41,69	64,30		
78	50,55	39,00	67,38	39,30	67,21	39,59	67,03	39,88	66,86	40,17	66,68	40,47	66,51	40,76	66,32	41,04	66,15	41,33	65,97	41,61	65,80	41,87	65,63	42,13	65,45	42,35	65,27	42,49	65,11		
79	50,42	39,50	68,24	39,80	68,07	40,10	67,89	40,39	67,70	40,69	67,54	40,98	67,36	41,28	67,17	41,57	66,99	41,87	66,80	42,13	66,62	42,41	66,44	42,69	66,26	42,91	66,08	43,13	65,90		
80	50,28	40,00	69,11	40,30	68,93	40,60	68,75	40,90	68,57	41,20	68,39	41,50	68,21	41,80	68,03	42,10	67,85	42,38	67,67	42,67	67,49	42,95	67,31	43,23	67,13	43,49	66,95	43,71	66,77		
81	50,15	40,50	69,97	40,81	69,79	41,11	69,61	41,41	69,43	41,72	69,25	42,02	69,06	42,32	68,88	42,62	68,70	42,91	68,52	43,20	68,34	43,48	68,16	43,76	67,98	44,00	67,80	44,26	67,62		
82	50,01	41,00	70,83	41,31	70,65	41,62	70,47	41,92	70,29	42,23	70,10	42,54	69,92	42,85	69,73	43,15	69,55	43,45	69,37	43,75	69,19	44,03	69,01	44,31	68,83	44,58	68,65	44,84	68,47		
83	49,88	41,50	71,70	41,81	71,52	42,13	71,33	42,44	71,14	42,75	70,96	43,06	70,77	43,37	70,58	43,67	70,39	43,97	70,20	44,27	70,01	44,57	69,83	44,86	69,64	45,12	69,45	45,39	69,27		
84	49,75	42,00	72,56	42,32	72,38	42,63	72,19	42,95	72,00	43,26	71,81	43,58	71,62	43,89	71,43	44,20	71,24	44,50	71,05	44,80	70,86	45,10	70,67	45,40	70,48	45,69	70,29	45,98	70,10		
85	49,61	42,50	73,43	42,82	73,24	43,14	73,05	43,46	72,86	43,78	72,67	44,10	72,48	44,41	72,28	44,73	72,09	45,03	71,90	45,33	71,71	45,63	71,52	45,93	71,33	46,22	71,14	46,51	70,95		
86	49,48	43,00	74,29	43,32	74,10	43,65	73,91	43,97	73,72	44,29	73,52	44,62	73,33	44,94	73,13	45,25	72,94	45,55	72,75	45,85	72,55	46,15	72,36	46,45	72,17	46,74	71,98	47,03	71,79		
87	49,34	43,50	75,15	43,83	74,96	44,16	74,77	44,48	74,57	44,81	74,38	45,11	74,18	45,46	73,98	45,78	73,79	46,08	73,59	46,38	73,40	46,68	73,21	46,98	73,02	47,27	72,83	47,57	72,64		
88	49,21	44,00	76,02	44,33	75,83	44,67	75,64	44,99	75,43	45,32	75,23	45,65	75,03	45,98	74,83	46,30	74,64	46,60	74,44	46,90	74,25	47,20	74,05	47,50	73,86	47,75	73,67	48,00	73,50		
89	49,08	44,50	76,88	44,84	76,69	45,17	76,48	45,50	76,29	45,84	76,09	46,17	75,89	46,51	75,68	46,83	75,49	47,13	75,29	47,44	75,10	47,70	74,91	47,99	74,72	48,25	74,53	48,50	74,34		
90	48,94	45,00	77,75	45,34	77,55	45,68	77,35	46,02	77,14	46,35	76,94	46,69	76,74	47,02	76,53	47,30	76,33	47,59	76,13	47,87	75,93	48,15	75,74	48,43	75,55	48,71	75,36	49,00	75,17		
91	48,81	45,50	78,61	45,84	78,41	46,19	78,21	46,53	78,00	46,87	77,80	47,21	77,59	47,55	77,38	47,88	77,18	48,17	76,97	48,45	76,77	48,73	76,57	49,01	76,38	49,27	76,19	49,53	76,00		
92	48,67	46,00	79,47	46,35	79,27	46,69	79,06	47,04	78,86	47,38	78,65	47,73	78,44	48,07	78,23	48,41	78,03	48,69	77,82	49,00	77,61	49,28	77,41	49,56	77,22	49,82	77,03	50,08	76,84		
93	48,54	46,50	80,34	46,85	80,13	47,20	79,92	47,55	79,72	47,90	79,51	48,24	79,30	48,59	79,08	48,94	78,87	49,22	78,66	49,50	78,45	49,78	78,24	50,05	78,05	50,31	77,86	50,57	77,67		
94	48,41	47,00	81,20	47,35	80,99	47,71	80,78	48,06</																							

32 Degrees																33 Degrees																																															
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.																																																	
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.																																																
1	0,85	0,53	0,85	0,53	0,84	0,54	0,84	0,54	0,84	0,54	0,84	0,55	0,83	0,55	0,83																																																
2	1,70	1,06	1,69	1,07	1,69	1,07	1,68	1,08	1,68	1,09	1,67	1,10	1,67	1,10	1,66																																																
3	2,54	1,59	2,54	1,60	2,53	1,61	2,52	1,62	2,52	1,63	2,51	1,64	2,50	1,66	2,49																																																
4	3,39	2,12	3,38	2,13	3,37	2,15	3,36	2,16	3,35	2,18	3,34	2,19	3,34	2,21	3,33																																																
5	4,24	2,65	4,23	2,67	4,22	2,69	4,20	2,79	4,19	2,72	4,18	2,74	4,17	2,76	4,16																																																
6	5,09	3,18	5,07	3,20	5,06	3,22	5,05	3,25	5,03	3,27	5,02	3,29	5,00	3,31	4,99																																																
7	5,94	3,71	5,92	3,73	5,90	3,76	5,89	3,78	5,87	3,81	5,85	3,84	5,84	3,86	5,82																																																
8	6,78	4,24	6,77	4,27	6,75	4,30	6,73	4,33	6,71	4,36	6,69	4,39	6,67	4,42	6,65																																																
9	7,63	4,77	7,61	4,80	7,59	4,84	7,57	4,87	7,55	4,90	7,53	4,93	7,50	4,97	7,48																																																
10	8,48	5,30	8,46	5,34	8,43	5,37	8,41	5,41	8,39	5,45	8,36	5,48	8,34	5,52	8,32																																																
11	9,33	5,83	9,30	5,87	9,27	5,91	9,25	5,95	9,22	5,99	9,20	6,03	9,17	6,07	9,15																																																
12	10,18	6,36	10,15	6,40	10,12	6,45	10,09	6,49	10,06	6,54	10,03	6,58	10,01	6,62	9,98																																																
13	11,02	6,89	10,99	6,94	10,96	6,98	10,93	7,03	10,90	7,08	10,87	7,13	10,84	7,17	10,81																																																
14	11,87	7,42	11,84	7,47	11,81	7,52	11,77	7,57	11,74	7,63	11,71	7,67	11,67	7,73	11,64																																																
15	12,72	7,95	12,69	8,00	12,65	8,06	12,61	8,11	12,58	8,17	12,54	8,22	12,51	8,28	12,47																																																
16	13,57	8,48	13,53	8,54	13,49	8,60	13,45	8,65	13,42	8,72	13,38	8,77	13,34	8,83	13,30																																																
17	14,42	9,01	14,38	9,07	14,34	9,13	14,29	9,19	14,26	9,26	14,21	9,32	14,18	9,38	14,13																																																
18	15,26	9,54	15,22	9,60	15,18	9,67	15,14	9,73	15,10	9,81	15,05	9,87	15,01	9,93	14,96																																																
19	16,11	10,07	16,07	10,14	16,02	10,21	16,08	10,27	16,04	10,35	15,89	10,41	15,84	10,45	15,80																																																
20	16,96	10,60	16,91	10,67	16,87	10,75	16,82	10,82	16,77	10,89	16,73	10,97	16,68	11,04	16,63																																																
21	17,81	11,13	17,76	11,21	17,71	11,28	17,50	11,36	17,61	11,44	17,56	11,51	17,51	11,59	17,46																																																
22	18,65	11,66	18,61	11,74	18,55	11,82	18,50	11,90	18,45	11,98	18,40	12,06	18,35	12,14	18,29																																																
23	19,50	12,19	19,45	12,27	19,40	12,36	19,34	12,44	19,29	12,53	19,23	12,61	19,18	12,66	19,12																																																
24	20,35	12,72	20,30	12,81	20,24	12,90	20,18	12,98	20,13	13,07	20,07	13,16	20,01	13,25	19,95																																																
25	21,20	13,25	21,14	13,34	21,08	13,44	21,03	13,52	20,97	13,62	20,91	13,71	20,85	13,80	20,78																																																
26	22,05	13,78	21,99	13,88	21,93	13,97	21,87	14,06	21,81	14,16	21,74	14,25	21,68	14,35	21,62																																																
27	22,90	14,31	22,84	14,41	22,77	14,51	2,61	14,61	22,65	14,71	22,58	14,80	22,52	14,90	22,45																																																
28	23,74	14,84	23,68	14,94	23,62	15,05	23,45	15,15	23,48	15,25	23,41	15,35	23,35	15,45	23,28																																																
29	24,59	15,37	24,53	15,48	24,45	15,58	24,39	15,69	24,32	15,80	24,25	15,90	24,18	16,01	24,11																																																
30	25,44	15,90	25,37	16,01	25,30	16,12	25,23	16,23	25,16	16,34	25,09	16,45	25,02	16,56	24,94																																																
31	26,29	16,43	26,22	16,54	26,14	16,66	26,07	16,77	26,00	16,88	25,92	17,00	25,85	17,11	25,78																																																
32	27,14	16,96	27,06	17,08	26,99	17,19	26,91	17,31	26,84	17,43	26,76	17,54	26,68	17,56	26,61																																																
33	27,99	17,49	27,91	17,61	27,83	17,73	27,75	17,85	27,68	17,97	27,60	18,09	27,52	18,21	27,44																																																
34	28,83	18,02	28,76	18,14	28,67	18,27	28,59	18,39	28,52	18,52	28,43	18,64	28,35	18,77	28,27																																																
35	29,68	18,55	29,60	18,68	29,52	18,80	29,44	18,93	29,35	19,06	29,27	19,19	29,19	19,32	29,10																																																
36	30,53	19,08	30,45	19,21	30,36	19,34	30,28	19,47	30,19	19,61	30,10	19,74	30,02	19,87	29,93																																																
37	31,38	19,61	31,29	19,75	31,20	19,88	31,12	20,02	31,03	20,15	30,94	20,28	30,85	20,42	30,76																																																
38	32,23	20,14	32,14	20,28	32,05	20,41	31,96	20,56	31,87	20,70	31,78	20,83	31,69	20,97	31,59																																																
39	33,07	20,67	32,99	20,81	32,89	20,95	32,80	21,10	32,71	21,24	32,61	21,38	32,54	21,53	32,42																																																
40	33,92	21,20	33,82	21,34	33,76	21,49	33,64	21,64	33,55	21,79	33,45	21,93	33,36	22,08	33,26																																																
41	34,77	21,73	34,67	21,88	34,58	22,03	34,48	22,18	34,39	22,33	34,29	22,48	34,19	22,63	34,09																																																
42	35,62	22,26	35,52	22,41	35,42	22,57	35,32	22,72	35,22	22,88	35,12	23,03	35,02	23,18	34,92																																																
43	36,47	22,79	36,37	22,95	36,26	23,10	36,16	23,26	36,06	23,42	35,96	23,58	35,86	23,73	35,75																																																
44	37,31	23,32	37,21	23,48	37,11	23,64	37,01	23,80	36,90	23,97	36,80	24,12	36,69	24,29	36,58																																																
45	38,16	23,85	38,06	24,01	37,95	24,18	37,85	24,34	37,74	24,51	37,63	24,67	37,53	24,84	37,41																																																
46	39,01	24,38	38,90	24,55	38,79	24,71	38,69	24,88	38,58	25,06	38,47	25,22	38,36	25,39	38,25																																																
47	39,86	24,91	39,75	25,08	39,64	25,25	39,53	25,43	39,42	25,90	39,30	25,77	39,19	25,94	39,08																																																
48	40,71	25,44	40,60	25,62	40,48	25,79	40,37	25,97	40,26	26,15	40,14	26,32	40,03	26,49	39,91																																																
49	41,55	25,97	41,44	26,15	41,32	26,32	41,21	26,51	41,10	26,69	40,98	26,86	40,86	27,05	40,74																																																
50	42,40	26,50	42,29	26,68	42,17	26,86	42,05	27,05	41,93	27,23	41,81	27,41	41,69	27,60	41,57																																																
51	43,25	27,03	43,13	27,21	43,01	27,40	42,89	27,59	42,77	27,80	42,65	27,96	42,53	28,15	42,41																																																
52	44,10	27,56	43,98	27,75	43,80	27,94	43,73	28,13	43,61	28,34	43,49	28,51	43,36	28,70	43,24																																																
53	44,95	28,09	44,82	28,28	44,70	28,48	44,57	28,67	44,45	28,89	44,32	29,06	44,20	29,25	44,07																																																
54	45,79	28,62	45,67	28,82	45,54	29,01	45,42	29,21	45,29	29,43	45,16	29,61	45,03	29,80	44,90																																																
55	46,64	29,15	46,52	29,35	46,33	29,55	46,26	29,75	46,13	29,98	45,99	30,15	45,86	30,36	45,73																																																
56	47,49	29,68	47,36	29,88	47,23	30,09	47,10	30,29	46,97	30,52	46,83	30,70	46,70	30,91	46,56																																																
57	48,34	30,21	48,21	30,42	48,07	30,62	47,94	30,84	47,81	31,07	47,67	31,25	47,53	31,46	47,39																																																
58	49,19	30,74	49,05	30,95	48,91	31,16	48,78	31,38	48,65	31,61	48,50	31,80	48,37	32,01	48,22																																																
59	50,03	31,27	49,90	31,49	49,76	31,70	49,62	31,92	49,48	32,16	49,34	32,35	49,20	32,56	49,05																																																
60	50,88	31,79	50,74	32,02	50,60	32,24	50,46	32,46	50,32	32,68	50,18	32,90	50,03	33,12	49,89																																																
Dep.		Lat.		Dep.		Lat.		Dep.		Lat.		Dep.		Lat.																																																	
0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.																																																	
58 Deg.																57 Degrees																56 Degrees																1,48															

TRAVERSE TABLE, 67.

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32 Degrees																33 Degrees																Distance
0 Min.								15 Min.								30 Min.								45 Min.								
Lat.				Dep.				Lat.				Dep.				Lat.				Dep.				Lat.				Dep.				
0 Min.				15 Min.				30 Min.				45 Min.				0 Min.				15 Min.				30 Min.				45 Min.				
61	51,73	33,32	51,59	32,55	51,45	32,77	51,30	33,00	51,16	33,22	51,01	33,44	50,87	33,67	50,72	33,89	50,58	34,11	50,43	34,33	50,29	34,55	50,14	34,77	50,00	35,00	49,46	35,22	49,31	35,44	61	
62	52,58	33,38	52,44	33,08	52,29	33,31	52,14	33,54	52,00	33,77	51,85	33,98	51,70	34,22	51,55	34,45	51,40	34,67	51,25	34,90	51,10	35,12	50,95	35,34	50,80	35,56	50,65	35,78	50,50	36,00	62	
63	53,42	33,38	53,28	33,13	53,13	33,35	52,98	34,08	52,84	34,31	52,68	34,53	52,53	34,77	52,38	35,00	52,23	35,22	52,08	35,44	51,93	35,66	51,78	35,88	51,63	36,11	51,48	36,33	51,33	36,55	63	
64	54,27	33,39	54,13	33,15	53,97	33,39	52,83	34,62	52,68	34,86	52,52	35,08	52,37	35,32	52,21	35,56	52,06	35,78	51,91	36,00	51,76	36,22	51,61	36,44	51,46	36,66	51,31	36,88	51,16	37,10	64	
65	55,12	33,44	54,97	33,19	53,82	33,43	52,67	35,16	52,51	35,40	52,36	35,63	52,20	35,88	52,04	36,11	51,89	36,33	51,74	36,55	51,59	36,77	51,44	36,99	51,29	37,22	51,14	37,44	50,99	37,66	65	
66	55,97	33,49	55,82	33,23	53,66	33,47	52,51	35,71	52,35	35,95	52,19	36,17	52,04	36,43	51,87	36,67	51,72	36,88	51,57	37,10	51,42	37,32	51,27	37,54	51,12	37,76	50,97	37,98	50,82	38,20	66	
67	56,81	33,50	56,67	33,27	53,50	33,51	52,35	36,01	52,19	36,25	52,03	36,47	51,87	36,71	51,72	36,93	51,57	37,15	51,42	37,37	51,27	37,59	51,12	37,81	50,97	38,03	50,82	38,25	50,67	38,47	67	
68	57,66	33,51	57,52	33,31	53,35	33,55	52,19	36,31	52,03	36,47	51,87	36,71	51,72	36,93	51,57	37,15	51,42	37,37	51,27	37,59	51,12	37,81	50,97	38,03	50,82	38,25	50,67	38,47	50,52	38,70	68	
69	58,51	33,52	58,37	33,35	53,19	33,59	52,03	36,56	51,87	36,71	51,72	36,93	51,57	37,15	51,42	37,37	51,27	37,59	51,12	37,81	50,97	38,03	50,82	38,25	50,67	38,47	50,52	38,70	50,37	38,93	69	
70	59,36	33,53	59,22	33,39	53,04	33,63	51,87	36,81	51,72	36,93	51,57	37,15	51,42	37,37	51,27	37,59	51,12	37,81	50,97	38,03	50,82	38,25	50,67	38,47	50,52	38,70	50,37	38,93	50,22	39,18	70	
71	60,21	33,54	60,07	33,43	52,48	33,67	51,72	37,01	51,57	37,15	51,42	37,37	51,27	37,59	51,12	37,81	50,97	38,03	50,82	38,25	50,67	38,47	50,52	38,70	50,37	38,93	50,22	39,18	50,07	39,43	71	
72	61,06	33,55	60,89	33,47	52,30	33,77	51,57	37,21	51,42	37,37	51,27	37,59	51,12	37,81	50,97	38,03	50,82	38,25	50,67	38,47	50,52	38,70	50,37	38,93	50,22	39,18	50,07	39,43	49,92	39,68	72	
73	61,91	33,56	61,74	33,51	52,15	33,81	51,42	37,41	51,27	37,59	51,12	37,81	50,97	38,03	50,82	38,25	50,67	38,47	50,52	38,70	50,37	38,93	50,22	39,18	50,07	39,43	49,92	39,68	49,77	39,93	73	
74	62,76	33,57	62,58	33,55	52,00	33,85	51,27	37,61	51,12	37,59	51,07	37,81	50,82	38,03	50,67	38,25	50,52	38,70	50,37	38,93	50,22	39,18	50,07	39,43	49,92	39,68	49,77	39,93	49,62	40,18	74	
75	63,60	33,58	63,43	33,59	51,45	33,89	51,12	37,81	50,97	38,03	50,82	38,25	50,67	38,47	50,52	38,70	50,37	38,93	50,22	39,18	50,07	39,43	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,43	75	
76	64,45	33,59	64,28	33,63	51,30	33,93	50,97	38,03	50,82	38,25	50,67	38,47	50,52	38,70	50,37	38,93	50,22	39,18	50,07	39,43	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,43	49,27	40,68	76	
77	65,30	33,60	65,12	33,67	51,15	33,97	50,82	38,25	50,67	38,47	50,52	38,70	50,37	38,93	50,22	39,18	50,07	39,43	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,07	40,93	48,87	41,18	77	
78	66,15	33,61	65,97	33,71	51,00	34,01	50,67	38,47	50,52	38,70	50,37	38,93	50,22	39,18	50,07	39,43	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,07	40,93	48,72	41,38	49,07	40,93	78	
79	67,00	33,62	66,81	33,75	50,45	34,05	50,52	38,70	50,37	38,93	50,22	39,18	50,07	39,43	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,07	40,93	48,57	41,58	48,87	41,78	48,62	41,98	79	
80	67,84	33,63	67,66	33,79	50,30	34,09	50,37	38,93	50,22	39,18	50,07	39,43	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,07	40,93	48,42	41,78	48,72	41,98	48,57	41,58	48,42	41,38	80	
81	68,69	33,64	68,50	33,83	50,15	34,13	50,22	39,18	50,07	39,43	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,07	40,93	48,27	41,98	48,57	41,58	48,42	41,38	48,27	41,98	48,12	42,18	81	
82	69,54	33,65	69,35	33,87	49,50	34,17	50,07	39,43	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	48,12	42,18	48,57	41,58	48,42	41,38	48,12	42,18	47,97	42,38	82	
83	70,39	33,66	70,20	33,91	49,35	34,21	50,00	39,68	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	47,97	42,38	48,42	41,38	48,12	42,18	47,97	42,38	47,82	42,58	83	
84	71,24	33,67	71,04	33,95	49,20	34,25	49,85	39,93	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	47,82	42,58	48,27	41,98	48,12	42,18	47,82	42,58	47,67	42,78	84	
85	72,08	33,68	71,89	33,99	49,05	34,29	49,70	40,18	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	47,67	42,78	48,12	42,18	47,82	42,58	47,67	42,78	47,52	42,98	85	
86	72,93	33,69	72,74	34,03	48,90	34,33	49,55	40,43	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	47,52	42,98	48,07	42,37	47,82	42,58	47,52	42,98	47,37	43,18	86	
87	73,78	33,70	73,58	34,07	48,75	34,37	49,40	40,68	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	47,37	43,18	48,07	42,37	47,82	42,58	47,37	43,18	47,22	43,38	87	
88	74,63	33,71	74,43	34,11	48,60	34,41	49,25	40,93	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	47,22	43,38	48,07	42,37	47,82	42,58	47,22	43,38	47,07	43,58	88	
89	75,48	33,72	75,27	34,15	48,45	34,45	49,10	41,18	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	47,07	43,58	48,07	42,37	47,82	42,58	47,07	43,58	46,92	43,78	89	
90	76,32	33,73	76,12	34,19	48,30	34,49	48,95	41,43	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	46,92	43,78	48,07	42,37	47,82	42,58	46,92	43,78	46,77	43,98	90	
91	77,17	33,74	76,95	34,23	48,15	34,53	48,80	41,68	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	46,77	43,98	48,07	42,37	47,82	42,58	46,77	43,98	46,62	44,18	91	
92	78,02	33,75	77,80	34,27	48,00	34,57	48,65	41,93	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	46,62	44,18	48,07	42,37	47,82	42,58	46,62	44,18	46,47	44,38	92	
93	78,87	33,76	78,65	34,31	47,45	34,61	48,50	42,18	49,92	39,68	49,77	39,93	49,62	40,18	49,47	40,18	49,27	40,18	49,07	40,93	46,47	44,38	48,07	42,37	47,82	42,58	46,47	44,38	46,32	44,58	93	
94	79,72	33,77	79,40	34,35	47,30	34,65	48,35	42,43	49,92	39,68	49,77	39,93																				

TRAVERSE TABLE, 67.

Distance	34 Degrees								35 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0,83	0,56	0,83	0,56	0,82	0,57	0,82	0,57	0,82	0,57	0,82	0,58	0,81	0,58	0,81	0,58	1
2	1,66	1,12	1,65	1,13	1,65	1,13	1,64	1,14	1,64	1,15	1,63	1,15	1,63	1,16	1,62	1,17	2
3	2,49	1,69	2,47	1,69	2,47	1,70	2,46	1,71	2,46	1,72	2,45	1,73	2,44	1,74	2,43	1,75	3
4	3,32	2,25	3,30	2,25	3,30	2,27	3,29	2,28	3,28	2,29	3,27	2,30	3,26	2,32	3,25	2,34	4
5	4,15	2,81	4,13	2,81	4,12	2,81	4,11	2,85	4,10	2,87	4,08	2,89	4,07	2,90	4,06	2,91	5
6	4,97	3,36	4,95	3,38	4,94	3,42	4,93	3,42	4,91	3,44	4,90	3,46	4,88	3,48	4,87	3,51	6
7	5,80	3,91	5,79	3,94	5,77	3,96	5,75	3,99	5,73	4,01	5,72	4,04	5,69	4,06	5,68	4,09	7
8	6,63	4,47	6,61	4,50	6,59	4,53	6,57	4,56	6,55	4,59	6,53	4,62	6,51	4,65	6,49	4,67	8
9	7,46	5,03	7,44	5,06	7,42	5,10	7,39	5,13	7,37	5,16	7,35	5,19	7,33	5,23	7,30	5,26	9
10	8,29	5,59	8,27	5,63	8,24	5,66	8,22	5,70	8,19	5,74	8,17	5,77	8,14	5,81	8,12	5,84	10
11	9,12	6,15	9,09	6,19	9,06	6,23	9,04	6,27	9,01	6,31	8,98	6,34	8,95	6,39	8,9	6,42	11
12	9,95	6,71	9,92	6,75	9,89	6,80	9,86	6,84	9,83	6,88	9,80	6,93	9,77	6,97	9,74	7,01	12
13	10,78	7,27	10,75	7,31	10,71	7,36	10,68	7,41	10,65	7,46	10,62	7,50	10,58	7,55	10,55	7,59	13
14	11,61	7,83	11,57	7,88	11,54	7,93	11,50	7,98	11,47	8,03	11,43	8,08	11,40	8,13	11,36	8,18	14
15	12,44	8,39	12,40	8,44	12,36	8,49	12,33	8,55	12,29	8,60	12,25	8,66	12,21	8,71	12,17	8,76	15
16	13,26	8,95	13,23	9,01	13,19	9,06	13,15	9,12	13,11	9,18	13,07	9,23	13,02	9,21	12,99	9,35	16
17	14,09	9,51	14,05	9,57	14,01	9,63	13,98	9,69	13,92	9,75	13,88	9,81	13,84	9,87	13,80	9,93	17
18	14,92	10,06	14,88	10,13	14,83	10,19	14,79	10,26	14,74	10,33	14,70	10,39	14,65	10,45	14,61	10,51	18
19	15,75	10,62	15,71	10,69	15,66	10,76	15,61	10,83	15,56	10,90	15,52	10,94	15,47	11,03	15,42	11,10	19
20	16,58	11,18	16,53	11,26	16,48	11,33	16,43	11,40	16,38	11,47	16,33	11,54	16,28	11,61	16,23	11,68	20
21	17,41	11,74	17,30	11,82	17,31	11,89	17,25	11,97	17,20	12,05	17,15	12,12	17,10	12,19	17,04	12,27	21
22	18,24	12,30	18,19	12,38	18,13	12,46	18,08	12,54	18,02	12,62	17,98	12,70	17,91	12,78	17,85	12,85	22
23	19,07	12,86	19,01	12,95	18,95	13,03	18,90	13,11	18,84	13,19	18,78	13,27	18,52	13,35	18,67	13,44	23
24	19,90	13,42	19,84	13,51	19,78	13,59	19,72	13,68	19,66	13,77	19,60	13,85	19,34	13,94	19,48	14,02	24
25	20,73	13,98	20,67	14,08	20,60	14,16	20,54	14,25	20,48	14,34	20,41	14,43	20,15	14,52	20,29	14,60	25
26	21,56	14,54	21,49	14,64	21,43	14,72	21,36	14,82	21,30	14,92	21,23	15,00	20,97	15,10	21,10	15,19	26
27	22,38	15,10	22,32	15,20	22,25	15,29	22,19	15,39	22,12	15,49	22,05	15,58	21,78	15,68	21,91	15,77	27
28	23,21	15,66	23,15	15,77	23,07	15,86	23,01	15,96	22,93	16,06	22,87	16,17	22,59	16,26	22,73	16,36	28
29	24,04	16,22	23,97	16,33	23,90	16,42	23,83	16,53	23,75	16,64	23,69	16,75	23,41	16,84	23,54	16,91	29
30	24,87	16,78	24,80	16,88	24,72	16,99	24,65	17,10	24,57	17,21	24,50	17,31	24,42	17,42	24,35	17,53	30
31	25,70	17,33	25,62	17,45	25,55	17,53	25,47	17,67	25,39	17,78	25,32	17,89	25,24	18,00	25,16	18,11	31
32	26,53	17,89	26,45	18,01	26,37	18,12	26,29	18,24	26,21	18,35	26,13	18,47	26,05	18,58	25,97	18,70	32
33	27,36	18,45	27,28	18,57	27,20	18,69	27,12	18,81	27,03	18,93	26,95	19,05	26,87	19,16	26,78	19,28	33
34	28,19	19,01	28,11	19,14	28,02	19,26	27,94	19,38	27,85	19,50	27,77	19,62	27,68	19,74	27,59	19,86	34
35	29,02	19,57	28,93	19,70	28,84	19,82	28,76	19,95	28,67	20,08	28,58	20,20	28,49	20,33	28,41	20,45	35
36	29,84	20,13	29,76	20,26	29,67	20,39	29,58	20,52	29,49	20,65	29,40	20,78	29,31	20,91	29,22	21,05	36
37	30,67	20,69	30,59	20,82	30,49	20,95	30,40	21,09	30,31	21,22	30,22	21,35	30,12	21,45	30,03	21,62	37
38	31,50	21,25	31,41	21,39	31,32	21,52	31,23	21,66	31,13	21,80	31,03	21,93	30,94	22,07	30,84	22,20	38
39	32,33	21,81	32,24	21,95	32,14	22,09	32,05	22,23	31,95	22,51	31,85	22,51	31,75	22,65	31,65	22,78	39
40	33,16	22,37	33,06	22,51	32,96	22,60	32,87	22,80	32,77	22,94	32,67	23,09	32,56	23,23	32,46	23,37	40
41	33,99	22,93	33,89	23,07	33,79	23,22	33,69	23,37	33,58	23,52	33,48	23,66	33,38	23,81	33,27	23,95	41
42	34,82	23,49	34,72	23,64	34,61	23,79	34,51	23,94	34,40	24,09	34,30	24,24	34,19	24,39	34,09	24,54	42
43	35,65	24,04	35,54	24,20	35,44	24,35	35,33	24,51	35,22	24,60	35,12	24,84	35,01	24,97	34,90	25,12	43
44	36,48	24,60	36,37	24,76	36,26	24,92	36,15	25,08	36,04	25,24	35,93	25,35	35,82	25,55	35,71	25,71	44
45	37,31	25,16	37,20	25,33	37,08	25,49	36,98	25,65	36,86	25,81	36,75	25,97	36,63	26,13	36,52	26,29	45
46	38,14	25,72	38,03	25,89	37,91	26,05	37,80	26,22	37,68	26,39	37,57	26,55	37,45	26,71	37,33	26,87	46
47	38,96	26,28	38,85	26,45	38,73	26,62	38,62	26,79	38,50	26,96	38,38	27,12	38,26	27,29	38,15	27,46	47
48	39,79	26,84	39,68	27,01	39,56	27,18	39,44	27,36	39,32	27,53	39,20	27,70	39,07	27,88	38,96	28,04	48
49	40,62	27,40	40,51	27,58	40,39	27,75	40,26	27,93	40,14	28,11	40,02	28,28	39,89	28,46	39,77	28,63	49
50	41,45	27,96	41,33	28,14	41,21	28,31	41,08	28,50	40,96	28,68	40,83	28,86	40,71	29,03	40,58	29,21	50
51	42,28	28,52	42,16	28,70	42,03	28,89	41,90	29,07	41,78	29,25	41,65	29,43	41,52	29,62	41,39	29,80	51
52	43,11	29,08	42,98	29,27	42,85	29,45	42,73	29,64	42,60	29,83	42,47	30,01	42,33	30,20	42,20	30,38	52
53	43,94	29,64	43,81	29,83	43,68	30,02	43,55	30,21	43,41	30,40	43,28	30,59	43,15	30,78	43,01	30,96	53
54	44,77	30,20	44,64	30,39	44,50	30,58	44,37	30,78	44,23	30,97	44,10	31,17	43,96	31,36	43,83	31,55	54
55	45,60	30,75	45,46	30,95	45,33	31,15	45,19	31,35	45,05	31,55	44,92	31,74	44,78	31,94	44,64	32,13	55
56	46,43	31,31	46,29	31,52	46,15	31,72	46,01	31,92	45,87	32,12	45,73	32,32	45,59	32,52	45,45	32,72	56
57	47,25	31,87	47,12	32,08	46,97	32,28	46,84	32,49	46,69	32,70	46,55	32,90	46,40	33,10	46,26	33,30	57
58	48,08	32,43	47,95	32,64	47,80	32,85	47,66	33,06	47,51	33,27	47,37	33,47	47,22	33,68	47,07	33,88	58
59	48,91	32,99	48,77	33,20	48,62	33,41	48,48	33,63	48,33	33,84	48,18	34,05	48,03	34,26	47,89	34,47	59
60	49,74	33,55	49,59	33,77	49,45	33,98	49,30	34,20	49,15	34,41	49,00	34,62	48,85	34,84	48,69	35,05	60
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance
	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.		
	56 Deg.						55 Degrees								54 Degrees		1,38

TRAVERSE TABLE, 67.

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34 Degrees														35 Degrees														36 Degrees													
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.											
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.										
61	50,57	34,11	50,42	34,33	50,27	34,55	50,12	34,77	49,97	34,99	49,81	35,21	49,66	35,42	49,51	35,64	61	50,57	34,11	50,42	34,33	50,27	34,55	50,12	34,77	49,97	34,99	49,81	35,21	49,66	35,42	49,51	35,64								
62	51,40	34,67	51,25	34,89	51,10	35,12	50,94	35,34	50,79	35,56	50,63	35,78	50,47	36,00	50,32	36,22	62	51,40	34,67	51,25	34,89	51,10	35,12	50,94	35,34	50,79	35,56	50,63	35,78	50,47	36,00	50,32	36,22								
63	52,23	35,23	52,08	35,46	51,92	35,68	51,76	35,91	51,6	36,14	51,45	36,37	51,29	36,58	51,13	36,81	63	52,23	35,23	52,08	35,46	51,92	35,68	51,76	35,91	51,6	36,14	51,45	36,37	51,29	36,58	51,13	36,81								
64	53,06	35,79	52,90	36,02	52,74	36,25	52,59	36,48	52,42	36,71	52,27	36,94	52,10	37,17	51,94	37,39	64	53,06	35,79	52,90	36,02	52,74	36,25	52,59	36,48	52,42	36,71	52,27	36,94	52,10	37,17	51,94	37,39								
65	53,89	36,35	53,73	36,58	53,51	36,81	53,41	37,05	53,24	37,28	53,07	37,51	52,92	37,75	52,75	37,98	65	53,89	36,35	53,73	36,58	53,51	36,81	53,41	37,05	53,24	37,28	53,07	37,51	52,92	37,75	52,75	37,98								
66	54,72	36,90	54,56	37,15	54,39	37,38	54,23	37,62	54,06	37,86	53,90	38,09	53,73	38,33	53,56	38,56	66	54,72	36,90	54,56	37,15	54,39	37,38	54,23	37,62	54,06	37,86	53,90	38,09	53,73	38,33	53,56	38,56								
67	55,54	37,46	55,38	37,71	55,22	37,95	55,05	38,19	54,88	38,43	54,72	38,67	54,54	38,91	54,38	39,14	67	55,54	37,46	55,38	37,71	55,22	37,95	55,05	38,19	54,88	38,43	54,72	38,67	54,54	38,91	54,38	39,14								
68	56,37	38,02	56,21	38,27	56,04	38,51	55,87	38,76	55,70	39,01	55,53	39,24	55,36	39,49	55,11	39,73	68	56,37	38,02	56,21	38,27	56,04	38,51	55,87	38,76	55,70	39,01	55,53	39,24	55,36	39,49	55,11	39,73								
69	57,20	38,58	57,04	38,83	56,86	39,08	56,70	39,33	56,52	39,58	56,35	39,82	56,17	40,07	55,00	40,31	69	57,20	38,58	57,04	38,83	56,86	39,08	56,70	39,33	56,52	39,58	56,35	39,82	56,17	40,07	55,00	40,31								
70	58,03	39,14	57,86	39,40	57,69	39,65	57,52	39,90	57,34	40,15	57,16	40,40	56,99	40,65	56,81	40,89	70	58,03	39,14	57,86	39,40	57,69	39,65	57,52	39,90	57,34	40,15	57,16	40,40	56,99	40,65	56,81	40,89								
71	58,80	39,70	58,69	39,96	58,51	40,21	58,34	40,47	58,16	40,72	57,98	40,98	57,80	41,23	57,62	41,48	71	58,80	39,70	58,69	39,96	58,51	40,21	58,34	40,47	58,16	40,72	57,98	40,98	57,80	41,23	57,62	41,48								
72	59,69	40,26	59,51	40,52	59,34	40,78	59,16	41,04	58,98	41,30	58,80	41,55	58,62	41,81	58,43	42,07	72	59,69	40,26	59,51	40,52	59,34	40,78	59,16	41,04	58,98	41,30	58,80	41,55	58,62	41,81	58,43	42,07								
73	60,52	40,82	60,34	41,08	60,16	41,35	59,98	41,61	59,80	41,87	59,61	42,13	59,43	42,39	59,25	42,65	73	60,52	40,82	60,34	41,08	60,16	41,35	59,98	41,61	59,80	41,87	59,61	42,13	59,43	42,39	59,25	42,65								
74	61,35	41,38	61,17	41,65	60,98	41,91	60,80	42,18	60,62	42,45	60,43	42,71	60,24	42,97	60,06	43,23	74	61,35	41,38	61,17	41,65	60,98	41,91	60,80	42,18	60,62	42,45	60,43	42,71	60,24	42,97	60,06	43,23								
75	62,18	41,94	62,00	42,21	61,81	42,48	61,63	42,75	61,44	43,02	61,25	43,29	61,06	43,55	60,87	43,82	75	62,18	41,94	62,00	42,21	61,81	42,48	61,63	42,75	61,44	43,02	61,25	43,29	61,06	43,55	60,87	43,82								
76	63,01	42,50	62,80	42,77	62,63	43,04	62,45	43,32	62,25	43,59	62,07	43,86	61,87	44,13	61,68	44,40	76	63,01	42,50	62,80	42,77	62,63	43,04	62,45	43,32	62,25	43,59	62,07	43,86	61,87	44,13	61,68	44,40								
77	63,84	43,06	63,65	43,34	63,46	43,61	63,27	43,89	63,07	44,17	62,88	44,44	62,69	44,72	62,49	44,99	77	63,84	43,06	63,65	43,34	63,46	43,61	63,27	43,89	63,07	44,17	62,88	44,44	62,69	44,72	62,49	44,99								
78	64,66	43,61	64,48	43,90	64,28	44,18	64,09	44,46	63,89	44,74	63,70	45,02	63,50	45,30	63,3	45,57	78	64,66	43,61	64,48	43,90	64,28	44,18	64,09	44,46	63,89	44,74	63,70	45,02	63,50	45,30	63,3	45,57								
79	65,49	44,17	65,30	44,46	65,10	44,74	64,91	45,03	64,71	45,32	64,52	45,59	64,31	45,88	64,12	46,15	79	65,49	44,17	65,30	44,46	65,10	44,74	64,91	45,03	64,71	45,32	64,52	45,59	64,31	45,88	64,12	46,15								
80	66,32	44,73	66,13	45,02	65,93	45,31	65,73	45,60	65,53	45,89	65,33	46,17	65,13	46,46	64,93	46,74	80	66,32	44,73	66,13	45,02	65,93	45,31	65,73	45,60	65,53	45,89	65,33	46,17	65,13	46,46	64,93	46,74								
81	67,15	45,29	66,95	45,59	66,75	45,88	66,54	46,17	66,35	46,44	66,15	46,74	65,94	47,04	65,74	47,32	81	67,15	45,29	66,95	45,59	66,75	45,88	66,54	46,17	66,35	46,44	66,15	46,74	65,94	47,04	65,74	47,32								
82	67,98	45,85	67,78	46,15	67,58	46,44	67,38	46,74	67,17	47,03	66,96	47,32	66,76	47,62	66,55	47,91	82	67,98	45,85	67,78	46,15	67,58	46,44	67,38	46,74	67,17	47,03	66,96	47,32	66,76	47,62	66,55	47,91								
83	68,81	46,41	68,61	46,71	68,40	47,01	68,20	47,31	67,99	47,61	67,78	47,90	67,57	48,20	67,36	48,49	83	68,81	46,41	68,61	46,71	68,40	47,01	68,20	47,31	67,99	47,61	67,78	47,90	67,57	48,20	67,36	48,49								
84	69,64	46,97	69,43	47,28	69,23	47,58	69,09	47,88	68,81	48,18	68,60	48,47	68,39	48,78	68,17	49,08	84	69,64	46,97	69,43	47,28	69,23	47,58	69,09	47,88	68,81	48,18	68,60	48,47	68,39	48,78	68,17	49,08								
85	70,47	47,53	70,26	47,84	70,05	48,14	69,84	48,45	69,63	48,76	69,42	49,05	69,20	49,36	68,95	49,66	85	70,47	47,53	70,26	47,84	70,05	48,14	69,84	48,45	69,63	48,76	69,42	49,05	69,20	49,36	68,95	49,66								
86	71,30	48,09	71,09	48,40	70,87	48,71	70,66	49,02	70,45	49,33	70,23	49,63	70,01	49,94	69,80	50,24	86	71,30	48,09	71,09	48,40	70,87	48,71	70,66	49,02	70,45	49,33	70,23	49,63	70,01	49,94	69,80	50,24								
87	72,13	48,65	71,92	48,96	71,70	49,27	71,49	49,59	71,26	49,90	71,05	50,20	70,83	50,52	70,61	50,83	87	72,13	48,65	71,92	48,96	71,70	49,27	71,49	49,59	71,26	49,90	71,05	50,20	70,83	50,52	70,61	50,83								
88	72,95	49,21	72,74	49,53	72,52	49,84	72,31	50,16	72,08	50,48	71,87	50,78	71,64	51,10	71,42	51,41	88	72,95	49,21	72,74	49,53	72,52	49,84	72,31	50,16	72,08	50,48	71,87	50,78	71,64	51,10	71,42	51,41								
89	73,78	49,77	73,57	50,09	73,35	50,41	73,13	50,73	72,90	51,05	72,68	51,36	72,46	51,68	72,23	52,00	89	73,78	49,77	73,57	50,09	73,35	50,41	73,13	50,73	72,90	51,05	72,68	51,36	72,46	51,68	72,23	52,00								
90	74,61	50,33	74,39	50,65	74,17	50,98	73,95	51,30	73,72	51,62	73,50	51,94	73,27	52,26	73,04	52,58	90	74,61																							

TRAVERSE TABLE, 67.

Distance	36 Degrees								37 Degrees								73		37 Degrees								73					
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.		
1	0,81	0,59	0,81	0,59	0,81	0,59	0,81	0,60	0,80	0,60	0,80	0,60	0,79	0,61	0,79	0,61	0,80	0,60	0,80	0,60	0,79	0,61	0,79	0,61	0,80	0,60	0,80	0,60	0,79	0,61		
2	1,62	1,18	1,61	1,18	1,61	1,19	1,60	1,20	1,60	1,20	1,59	1,21	1,59	1,22	1,58	1,22	1,60	1,20	1,60	1,20	1,59	1,21	1,59	1,22	1,60	1,20	1,60	1,20	1,59	1,22		
3	2,43	1,76	2,42	1,77	2,41	1,78	2,40	1,79	2,40	1,80	2,39	1,82	2,38	1,83	2,37	1,84	2,40	1,80	2,40	1,80	2,39	1,82	2,38	1,83	2,37	1,84	2,40	1,80	2,40	1,80		
4	3,24	2,35	3,23	2,36	3,21	2,38	3,20	2,39	3,20	2,41	3,18	2,42	3,17	2,43	3,16	2,45	3,24	2,35	3,23	2,36	3,21	2,38	3,20	2,39	3,20	2,41	3,18	2,42	3,17	2,43		
5	4,04	2,94	4,03	2,96	4,02	2,97	4,01	2,99	3,99	3,01	3,98	3,03	3,97	3,04	3,95	3,06	4,04	2,94	4,03	2,96	4,02	2,97	4,01	2,99	3,99	3,01	3,98	3,03	3,97	3,04		
6	4,85	3,53	4,84	3,55	4,82	3,57	4,81	3,59	4,79	3,61	4,78	3,63	4,76	3,65	4,74	3,67	4,85	3,53	4,84	3,55	4,82	3,57	4,81	3,59	4,79	3,61	4,78	3,63	4,76	3,65		
7	5,66	4,11	5,64	4,14	5,63	4,16	5,61	4,19	5,59	4,21	5,57	4,24	5,55	4,26	5,53	4,29	5,66	4,11	5,64	4,14	5,63	4,16	5,61	4,19	5,59	4,21	5,57	4,24	5,55	4,26		
8	6,47	4,70	6,45	4,73	6,43	4,76	6,41	4,79	6,39	4,81	6,37	4,84	6,35	4,87	6,33	4,90	6,47	4,70	6,45	4,73	6,43	4,76	6,41	4,79	6,39	4,81	6,37	4,84	6,35	4,87		
9	7,28	5,29	7,26	5,32	7,23	5,35	7,21	5,38	7,19	5,42	7,16	5,45	7,14	5,48	7,12	5,51	7,28	5,29	7,26	5,32	7,23	5,35	7,21	5,38	7,19	5,42	7,16	5,45	7,14	5,48		
10	8,09	5,88	8,06	5,91	8,04	5,95	8,01	5,98	7,99	6,02	7,96	6,05	7,93	6,09	7,91	6,12	8,09	5,88	8,06	5,91	8,04	5,95	8,01	5,98	7,99	6,02	7,96	6,05	7,93	6,09		
11	8,90	6,47	8,87	6,50	8,84	6,54	8,81	6,58	8,78	6,62	8,76	6,66	8,73	6,70	8,70	6,73	8,90	6,47	8,87	6,50	8,84	6,54	8,81	6,58	8,78	6,62	8,76	6,66	8,73	6,70		
12	9,71	7,06	9,68	7,10	9,65	7,14	9,61	7,18	9,58	7,22	9,55	7,26	9,52	7,30	9,49	7,33	9,71	7,06	9,68	7,10	9,65	7,14	9,61	7,18	9,58	7,22	9,55	7,26	9,52	7,30		
13	10,52	7,65	10,48	7,69	10,45	7,73	10,41	7,78	10,38	7,82	10,35	7,87	10,31	7,91	10,28	7,95	10,52	7,65	10,48	7,69	10,45	7,73	10,41	7,78	10,38	7,82	10,35	7,87	10,31	7,91		
14	11,33	8,23	11,29	8,28	11,25	8,33	11,21	8,37	11,18	8,43	11,14	8,47	11,11	8,52	11,07	8,57	11,33	8,23	11,29	8,28	11,25	8,33	11,21	8,37	11,18	8,43	11,14	8,47	11,11	8,52		
15	12,14	8,82	12,09	8,87	12,05	8,93	12,01	8,96	11,98	9,03	11,94	9,08	11,90	9,13	11,86	9,19	12,14	8,82	12,09	8,87	12,05	8,93	12,01	8,96	11,98	9,03	11,94	9,08	11,90	9,13		
16	12,95	9,41	12,90	9,46	12,86	9,52	12,82	9,56	12,77	9,63	12,74	9,68	12,69	9,74	12,65	9,79	12,95	9,41	12,90	9,46	12,86	9,52	12,82	9,56	12,77	9,63	12,74	9,68	12,69	9,74		
17	13,76	10,00	13,71	10,06	13,67	10,11	13,62	10,16	13,57	10,23	13,53	10,29	13,48	10,35	13,44	10,41	13,76	10,00	13,71	10,06	13,67	10,11	13,62	10,16	13,57	10,23	13,53	10,29	13,48	10,35		
18	14,57	10,58	14,51	10,64	14,47	10,71	14,42	10,76	14,37	10,83	14,33	10,89	14,28	10,96	14,23	11,02	14,57	10,58	14,51	10,64	14,47	10,71	14,42	10,76	14,37	10,83	14,33	10,89	14,28	10,96		
19	15,38	11,17	15,32	11,23	15,27	11,30	15,22	11,36	15,17	11,44	15,12	11,50	15,07	11,57	15,02	11,08	15,38	11,17	15,32	11,23	15,27	11,30	15,22	11,36	15,17	11,44	15,12	11,50	15,07	11,57		
20	16,19	11,76	16,13	11,83	16,08	11,90	16,02	11,96	15,97	12,04	15,92	12,11	15,87	12,17	15,81	12,24	16,19	11,76	16,13	11,83	16,08	11,90	16,02	11,96	15,97	12,04	15,92	12,11	15,87	12,17		
21	16,99	12,35	16,93	12,42	16,88	12,49	16,83	12,56	16,77	12,64	16,72	12,71	16,66	12,78	16,60	12,86	16,99	12,35	16,93	12,42	16,88	12,49	16,83	12,56	16,77	12,64	16,72	12,71	16,66	12,78		
22	17,80	12,94	17,74	13,01	17,68	13,09	17,63	13,16	17,57	13,24	17,51	13,31	17,45	13,39	17,40	13,47	17,80	12,94	17,74	13,01	17,68	13,09	17,63	13,16	17,57	13,24	17,51	13,31	17,45	13,39		
23	18,61	13,53	18,55	13,60	18,49	13,68	18,43	13,76	18,37	13,84	18,31	13,92	18,25	14,00	18,19	14,08	18,61	13,53	18,55	13,60	18,49	13,68	18,43	13,76	18,37	13,84	18,31	13,92	18,25	14,00		
24	19,42	14,12	19,35	14,19	19,29	14,28	19,23	14,36	19,17	14,44	19,10	14,53	19,04	14,61	18,98	14,69	19,42	14,12	19,35	14,19	19,29	14,28	19,23	14,36	19,17	14,44	19,10	14,53	19,04	14,61		
25	20,23	14,71	20,16	14,78	20,10	14,87	20,03	14,96	19,97	15,05	19,90	15,13	19,83	15,22	19,77	15,30	20,23	14,71	20,16	14,78	20,10	14,87	20,03	14,96	19,97	15,05	19,90	15,13	19,83	15,22		
26	21,04	15,30	20,97	15,37	20,89	15,47	20,83	15,55	20,77	15,65	20,70	15,74	20,62	15,83	20,56	15,92	21,04	15,30	20,97	15,37	20,89	15,47	20,83	15,55	20,77	15,65	20,70	15,74	20,62	15,83		
27	21,85	15,89	21,77	15,96	21,69	16,06	21,63	16,15	21,57	16,25	21,49	16,34	21,42	16,44	21,35	16,53	21,85	15,89	21,77	15,96	21,69	16,06	21,63	16,15	21,57	16,25	21,49	16,34	21,42	16,44		
28	22,66	16,48	22,58	16,55	22,50	16,66	22,43	16,75	22,36	16,85	22,29	16,95	22,21	17,05	22,14	17,14	22,66	16,48	22,58	16,55	22,50	16,66	22,43	16,75	22,36	16,85	22,29	16,95	22,21	17,05		
29	23,47	17,07	23,38	17,14	23,31	17,25	23,23	17,35	23,16	17,45	23,08	17,55	23,00	17,66	22,93	17,75	23,47	17,07	23,38	17,14	23,31	17,25	23,23	17,35	23,16	17,45	23,08	17,55	23,00	17,66		
30	24,28	17,66	24,19	17,74	24,12	17,84	24,04	17,95	23,96	18,05	23,88	18,16	23,79	18,26	23,72	18,37	24,28	17,66	24,19	17,74	24,12	17,84	24,04	17,95	23,96	18,05	23,88	18,16	23,79	18,26		
31	25,09	18,25	25,00	18,33	24,92	18,44	24,84	18,55	24,76	18,66	24,68	18,76	24,59	18,87	24,51	18,99	25,09	18,25	25,00	18,33	24,92	18,44	24,84	18,55	24,76	18,66	24,68	18,76	24,59	18,87		
32	25,90	18,84	25,80	18,92	25,72	19,03	25,64	19,15	25,56	19,26	25,47	19,37	25,39	19,48	25,30	19,59	25,90	18,84	25,80	18,92	25,72	19,03	25,64	19,15	25,56	19,26	25,47	19,37	25,39	19,48		
33	26,71	19,43	26,61	19,51	26,53	19,63	26,44	19,74	26,36	19,86																						

TRAVERSE TABLE, 67.

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36 Degrees										73		37 Degrees										75		Distance
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
61	49,55	35,85	49,19	36,07	49,04	36,28	48,88	35,50	48,72	36,71	48,56	36,92	48,39	37,13	48,23	37,34	48,06	37,55	47,88	37,79	47,71	38,00	47,52	61
62	50,16	36,44	49,99	36,66	49,84	36,88	49,68	37,09	49,52	37,31	49,35	37,53	49,19	37,74	49,02	37,96	48,84	38,17	48,66	38,41	48,49	38,62	48,36	62
63	50,77	37,03	50,80	37,25	50,64	37,47	50,48	37,69	50,31	37,91	50,15	38,13	49,98	38,35	49,81	38,57	48,62	38,78	48,49	39,00	48,30	39,21	48,06	63
64	51,38	37,62	51,61	37,84	51,45	38,07	51,28	38,29	51,11	38,52	50,94	38,74	50,77	38,96	50,60	39,18	48,38	39,39	48,19	39,60	47,98	39,81	47,71	64
65	51,99	38,21	52,42	38,43	52,25	38,66	52,08	38,89	51,91	39,12	51,74	39,34	51,57	39,57	51,40	39,79	47,98	39,99	47,79	40,00	47,58	40,19	47,37	65
66	52,59	38,80	53,22	39,02	53,06	39,26	52,88	39,49	52,71	39,72	52,54	39,95	52,36	40,18	52,19	40,40	47,77	40,61	47,57	40,82	47,36	41,03	47,15	66
67	53,19	39,39	54,03	39,62	53,86	39,85	53,68	40,08	53,51	40,32	53,33	40,55	53,15	40,79	52,98	41,02	47,56	41,23	47,42	41,44	47,01	41,65	46,79	67
68	53,79	40,00	54,83	40,21	54,66	40,45	54,48	40,68	54,31	40,92	54,13	41,16	53,94	41,40	53,77	41,63	47,35	41,84	47,21	42,05	46,80	42,26	46,62	68
69	54,39	40,60	55,63	40,80	55,47	41,04	55,28	41,28	55,11	41,53	54,92	41,76	54,74	42,00	54,56	42,24	47,14	42,35	47,00	42,56	46,60	42,77	46,42	69
70	54,99	41,20	56,43	41,39	56,27	41,64	56,09	41,88	55,90	42,13	55,72	42,37	55,54	42,61	55,35	42,85	46,93	43,06	46,79	43,27	46,59	43,49	46,40	70
71	55,59	41,79	57,23	41,98	57,07	42,23	56,89	42,48	56,70	42,73	56,52	42,97	56,34	43,22	56,14	43,47	46,72	43,68	46,58	43,89	46,39	44,11	46,20	71
72	56,19	42,38	58,03	42,57	57,88	42,83	57,69	43,08	57,50	43,33	57,31	43,58	57,14	43,83	56,93	44,08	46,51	44,29	46,37	44,50	46,18	44,71	45,93	72
73	56,79	42,97	58,83	43,16	58,68	43,42	58,49	43,68	58,30	43,93	58,11	44,18	57,93	44,44	57,72	44,69	46,34	44,95	46,11	45,16	46,32	45,37	46,08	73
74	57,39	43,56	59,63	43,76	59,49	44,02	59,29	44,27	59,10	44,53	58,90	44,79	58,73	45,05	58,51	45,30	46,11	45,62	45,38	45,91	46,09	46,26	46,43	74
75	57,99	44,15	60,43	44,35	60,29	44,61	60,09	44,87	59,90	45,14	59,70	45,39	59,52	45,66	59,30	45,91	45,91	46,23	45,99	46,46	46,63	46,80	46,97	75
76	58,59	44,74	61,23	44,95	61,09	45,21	60,89	45,47	60,70	45,74	60,49	46,00	60,31	46,27	60,09	46,53	45,72	46,85	46,61	47,02	47,19	47,36	47,53	76
77	59,19	45,33	62,03	45,53	61,90	45,80	61,69	46,07	61,50	46,34	61,29	46,60	61,11	46,88	60,88	47,14	45,51	47,47	47,23	47,60	47,77	47,94	48,11	77
78	59,79	45,92	62,83	46,11	62,70	46,40	62,50	46,67	62,30	46,94	62,09	47,21	61,90	47,48	61,68	47,75	45,30	48,07	47,83	48,20	48,37	48,54	48,71	78
79	60,39	46,51	63,63	46,71	63,50	46,90	63,30	47,27	63,10	47,54	62,88	47,81	62,69	48,09	62,47	48,36	45,09	48,69	48,45	48,82	49,00	49,17	49,34	79
80	60,99	47,10	64,43	47,30	64,31	47,59	64,10	47,87	63,89	48,15	63,68	48,42	63,47	48,70	63,25	48,98	44,88	49,18	48,94	49,31	49,48	49,65	49,82	80
81	61,59	47,69	65,23	47,90	65,11	48,18	64,90	48,46	64,69	48,75	64,48	49,03	64,26	49,31	64,05	49,59	44,67	49,88	49,64	50,01	50,18	50,35	50,52	81
82	62,19	48,28	66,03	48,49	65,92	48,78	65,71	49,06	65,49	49,35	65,27	49,63	65,05	49,92	64,84	50,20	44,46	50,51	50,27	50,64	50,81	50,98	51,15	82
83	62,79	48,87	66,83	49,08	66,72	49,37	66,50	49,66	66,29	49,95	66,07	50,24	65,85	50,53	65,63	50,81	44,25	51,12	50,88	51,25	51,42	51,59	51,76	83
84	63,39	49,46	67,63	49,67	67,52	49,97	67,30	50,26	67,09	50,55	66,86	50,84	66,64	51,14	66,42	51,43	44,04	51,73	51,49	51,86	52,03	52,20	52,37	84
85	63,99	50,05	68,43	50,26	68,33	50,56	68,10	50,86	67,89	51,16	67,66	51,45	67,43	51,75	67,21	52,04	43,83	52,52	52,28	52,65	52,82	52,99	53,16	85
86	64,59	50,64	69,23	50,85	69,11	51,16	68,91	51,45	68,68	51,76	68,46	52,05	68,23	52,35	68,00	52,65	43,62	53,01	52,77	53,14	53,31	53,48	53,65	86
87	65,19	51,23	70,03	51,44	69,94	51,75	69,71	52,05	69,48	52,36	69,25	52,66	69,02	52,96	68,79	53,26	43,41	53,57	53,33	53,70	53,87	54,04	54,21	87
88	65,79	51,82	70,83	52,03	70,74	52,35	70,51	52,65	70,28	52,96	70,05	53,26	69,81	53,57	69,58	53,87	43,20	54,37	54,13	54,50	54,67	54,84	55,01	88
89	66,39	52,41	71,63	52,62	71,54	52,94	71,31	53,25	71,08	53,56	70,84	53,87	70,60	54,18	70,37	54,49	42,99	55,17	54,93	55,30	55,47	55,64	55,81	89
90	66,99	53,00	72,43	53,22	72,35	53,53	72,11	53,85	71,88	54,16	71,63	54,48	71,40	54,79	71,16	55,10	42,78	55,97	55,73	56,10	56,27	56,44	56,61	90
91	67,59	53,59	73,23	53,81	73,15	54,13	72,91	54,45	72,68	54,77	72,44	55,08	72,19	55,40	71,95	56,71	42,57	56,77	56,53	56,90	57,07	57,24	57,41	91
92	68,19	54,18	74,03	54,40	73,95	54,72	73,71	55,04	73,48	55,37	73,23	55,69	72,99	56,01	72,74	56,32	42,36	57,57	57,33	57,70	57,87	58,04	58,21	92
93	68,79	54,77	74,83	54,99	74,76	55,32	74,52	55,64	74,27	55,97	74,03	56,29	73,78	56,61	73,53	56,94	42,15	58,37	58,13	58,50	58,67	58,84	59,01	93
94	69,39	55,36	75,63	55,58	75,56	55,91	75,32	56,24	75,07	56,57	74,82	56,90	74,57	57,22	74,33	57,55	41,94	59,17	58,93	59,30	59,47	59,64	59,81	94
95	69,99	55,95	76,43	56,17	76,37	56,51	76,12	56,84	75,87	57,17	75,62	57,50	75,37	57,83	75,12	58,16	41,73	60,00	59,76	60,13	60,30	60,47	60,64	95
96	70,59	56,54	77,23	56,76	77,17	57,10	76,92	57,44	76,67	57,78	76,42	58,11	76,16	58,44	75,91	58,77	41,52	60,80	60,56	60,93	61,10	61,27	61,44	96
97	71,19	57,13	78,03	57,35	77,97	57,70	77,72	58,03	77,47	58,38	77,21	58,71	76,95	59,05	76,70	59,38	41,31	61,60	61,36	61,73	61,90	62,07	62,24	97
98	71,79	57,72	78,83	57,95	78,70	58,29	78,52	58,63	78,27	58,98	78,01	59,32	77,75	59,66	77,49	60,00	41,10	62,40	62,16	62,53	62,70	62,87	63,04	98
99	72,39	58,31	79,63	58,54	79,50	58,89	79,32	59,23	79,07	59,58	78,80	60,02	78,54	60,27	78,28	60,61	40,89	63,20	62,96	63,33	63,50	63,67	63,84	99
100	72,99	58,90	80,43	59,13	80,32	59,48	80,12	59,83	79,86	60,18	79,60	60,53</												

Distance	38 Degrees								39 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0,79	0,62	0,79	0,62	0,78	0,63	0,78	0,63	0,78	0,63	0,77	0,63	0,77	0,64	0,77	0,64	1
2	1,58	1,23	1,57	1,24	1,57	1,25	1,56	1,25	1,55	1,26	1,55	1,27	1,54	1,27	1,54	1,28	2
3	2,36	1,85	2,36	1,86	2,35	1,87	2,34	1,88	2,33	1,89	2,32	1,90	2,32	1,91	2,31	1,92	3
4	3,15	2,46	3,14	2,48	3,13	2,49	3,12	2,50	3,11	2,52	3,10	2,53	3,09	2,54	3,08	2,55	4
5	3,94	3,08	3,93	3,10	3,91	3,11	3,90	3,13	3,89	3,15	3,87	3,16	3,86	3,18	3,84	3,20	5
6	4,73	3,69	4,71	3,72	4,70	3,74	4,68	3,76	4,66	3,78	4,65	3,80	4,63	3,82	4,61	3,84	6
7	5,52	4,31	5,50	4,33	5,48	4,36	5,46	4,38	5,44	4,41	5,42	4,43	5,40	4,45	5,38	4,48	7
8	6,30	4,93	6,28	4,95	6,26	4,98	6,24	5,01	6,22	5,04	6,20	5,07	6,17	5,09	6,15	5,12	8
9	7,09	5,54	7,07	5,57	7,04	5,60	7,02	5,63	6,99	5,66	6,97	5,69	6,95	5,73	6,92	5,76	9
10	7,88	6,16	7,85	6,19	7,83	6,23	7,80	6,26	7,77	6,29	7,74	6,33	7,72	6,36	7,69	6,39	10
11	8,67	6,77	8,64	6,81	8,61	6,85	8,58	6,89	8,55	6,92	8,52	6,97	8,49	6,99	8,46	7,03	11
12	9,46	7,39	9,42	7,43	9,39	7,47	9,36	7,51	9,33	7,55	9,29	7,59	9,26	7,63	9,23	7,67	12
13	10,25	8,00	10,21	8,05	10,17	8,09	10,14	8,14	10,10	8,18	10,07	8,23	10,03	8,27	10,00	8,31	13
14	11,04	8,62	10,99	8,67	10,96	8,72	10,92	8,76	10,88	8,81	10,84	8,86	10,80	8,91	10,76	8,95	14
15	11,82	9,24	11,78	9,29	11,74	9,34	11,70	9,39	11,65	9,44	11,62	9,49	11,58	9,54	11,53	9,59	15
16	12,61	9,85	12,56	9,91	12,52	9,96	12,48	10,02	12,43	10,07	12,39	10,13	12,35	10,18	12,30	10,23	16
17	13,40	10,47	13,35	10,52	13,31	10,57	13,26	10,64	13,21	10,70	13,16	10,76	13,12	10,81	13,07	10,87	17
18	14,18	11,08	14,13	11,14	14,09	11,21	14,04	11,27	13,99	11,33	13,94	11,39	13,89	11,45	13,84	11,51	18
19	14,97	11,70	14,92	11,76	14,87	11,83	14,82	11,89	14,77	11,96	14,71	12,02	14,66	12,09	14,61	12,15	19
20	15,76	12,31	15,71	12,38	15,65	12,45	15,60	12,52	15,54	12,59	15,49	12,65	15,43	12,72	15,38	12,79	20
21	16,55	12,93	16,49	13,00	16,44	13,07	16,38	13,14	16,32	13,22	16,26	13,29	16,20	13,36	16,15	13,44	21
22	17,34	13,55	17,27	13,62	17,22	13,70	17,16	13,77	17,10	13,85	17,04	13,92	16,98	13,99	16,91	14,07	22
23	18,12	14,16	18,06	14,24	18,00	14,32	17,94	14,40	17,87	14,47	17,81	14,55	17,75	14,63	17,68	14,71	23
24	18,91	14,78	18,85	14,86	18,78	14,94	18,72	15,02	18,65	15,10	18,58	15,18	18,52	15,26	18,45	15,35	24
25	19,70	15,39	19,63	15,46	19,57	15,57	19,50	15,65	19,43	15,73	19,36	15,82	19,29	15,90	19,22	15,98	25
26	20,40	16,01	20,41	16,08	20,35	16,19	20,28	16,27	20,21	16,36	20,13	16,45	20,06	16,55	19,99	16,02	26
27	21,28	16,63	21,20	16,70	21,13	16,81	21,06	16,90	20,98	16,99	20,91	17,08	20,84	17,11	20,76	17,21	27
28	22,06	17,24	21,99	17,31	21,92	17,43	21,84	17,53	21,76	17,62	21,69	17,72	21,61	17,81	21,53	17,90	28
29	22,85	17,85	22,77	17,93	22,70	18,06	22,62	18,15	22,54	18,25	22,46	18,35	22,38	18,44	22,29	18,51	29
30	23,64	18,47	23,56	18,57	23,48	18,68	23,40	18,78	23,32	18,88	23,23	18,98	23,15	19,08	23,07	19,18	30
31	24,43	19,09	24,35	19,19	24,26	19,30	24,18	19,40	24,09	19,51	24,01	19,61	23,93	19,72	23,83	19,82	31
32	25,22	19,70	25,13	19,81	25,04	19,92	24,96	20,03	24,87	20,14	24,78	20,25	24,69	20,35	24,60	20,46	32
33	26,00	20,32	25,92	20,43	25,83	20,54	25,74	20,66	25,65	20,77	25,55	20,88	25,47	20,99	25,37	21,07	33
34	26,79	20,93	26,70	21,05	26,61	21,17	26,52	21,28	26,43	21,40	26,33	21,51	26,24	21,63	26,14	21,74	34
35	27,58	21,55	27,49	21,67	27,39	21,79	27,30	21,91	27,20	22,03	27,10	22,15	27,01	22,26	26,91	22,38	35
36	28,37	22,17	28,27	22,29	28,18	22,41	28,08	22,53	27,98	22,65	27,88	22,78	27,78	22,90	27,68	23,02	36
37	29,16	22,78	29,06	22,91	28,96	23,04	28,86	23,16	28,75	23,28	28,65	23,41	28,55	23,53	28,45	23,66	37
38	29,94	23,40	29,84	23,53	29,74	23,66	29,64	23,79	29,53	23,91	29,42	24,05	29,33	24,17	29,22	24,35	38
39	30,73	24,01	30,63	24,14	30,53	24,22	30,42	24,41	30,31	24,54	30,20	24,68	30,09	24,81	29,99	24,95	39
40	31,52	24,63	31,41	24,76	31,30	24,90	31,20	25,04	31,09	25,17	30,98	25,31	30,87	25,44	30,75	25,58	40
41	32,31	25,24	32,20	25,38	32,09	25,52	31,98	25,66	31,87	25,80	31,75	25,94	31,62	26,08	31,52	26,22	41
42	33,10	25,86	32,98	26,00	32,87	26,15	32,76	26,29	32,64	26,43	32,52	26,57	32,41	26,72	32,29	26,84	42
43	33,88	26,47	33,77	26,62	33,65	26,77	33,54	26,92	33,42	27,06	33,30	27,21	33,18	27,35	33,06	27,50	43
44	34,67	27,09	34,55	27,24	34,44	27,39	34,32	27,54	34,20	27,70	34,07	27,84	33,95	27,99	33,83	28,13	44
45	35,46	27,71	35,34	27,86	35,22	28,02	35,10	28,17	34,97	28,32	34,85	28,47	34,73	28,62	34,60	28,77	45
46	36,25	28,34	36,12	28,48	36,00	28,64	35,88	28,79	35,75	28,95	35,62	29,11	35,50	29,26	35,37	29,41	46
47	37,04	28,94	36,91	29,10	36,78	29,26	36,66	29,42	36,53	29,58	36,39	29,74	36,27	29,90	36,14	30,05	47
48	37,82	29,55	37,69	29,72	37,57	29,88	37,44	30,05	37,30	30,21	37,17	30,37	37,04	30,53	36,91	30,69	48
49	38,61	30,17	38,48	30,34	38,35	30,50	38,22	30,67	38,08	30,84	37,94	31,01	37,81	31,17	37,68	31,33	49
50	39,40	30,78	39,27	30,96	39,13	31,13	38,99	31,30	38,86	31,47	38,72	31,64	38,58	31,80	38,44	31,97	50
51	40,19	31,40	40,05	31,57	39,91	31,75	39,77	31,92	39,64	32,10	39,49	32,27	39,35	32,44	39,21	32,61	51
52	40,98	32,02	40,84	32,19	40,70	32,37	40,55	32,55	40,41	32,72	40,27	32,90	40,13	33,08	39,98	33,25	52
53	41,77	32,63	41,62	32,81	41,48	33,00	41,33	33,17	41,19	33,35	41,04	33,54	40,90	33,71	40,75	33,89	53
54	42,55	33,25	42,41	33,43	42,26	33,62	42,11	33,80	41,97	33,98	41,82	34,17	41,67	34,34	41,52	34,53	54
55	43,34	33,86	43,19	34,05	43,05	34,24	42,89	34,43	42,75	34,61	42,59	34,80	42,44	34,98	42,29	35,17	55
56	44,13	34,48	43,98	34,67	43,83	34,86	43,67	35,05	43,52	35,24	43,36	35,43	43,21	35,62	43,06	35,81	56
57	44,92	35,10	44,76	35,29	44,61	35,49	44,45	35,68	44,30	35,87	44,15	36,07	43,99	36,26	43,83	36,45	57
58	45,71	35,71	45,55	35,91	45,39	36,11	45,23	36,30	45,07	36,50	44,93	36,70	44,76	36,89</			

TRAVERSE TABLE, 67.

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38 Degrees																39 Degrees																Distance.
0 Min.				15 Min.				30 Min.				45 Min.				0 Min.				15 Min.				30 Min.				45 Min.				
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.			
61	37,56	47,90	37,76	47,74	37,97	47,57	38,18	47,41	38,39	47,24	38,60	47,07	38,80	46,90	39,01	61	38,39	47,24	38,60	47,07	38,80	46,90	39,01	61	38,39	47,24	38,60	47,07	38,80	46,90	39,01	
62	38,17	48,69	38,38	48,52	38,60	48,35	38,81	48,18	39,02	48,01	39,23	47,84	39,43	47,67	39,64	62	39,02	48,01	39,23	47,84	39,43	47,67	39,64	62	39,02	48,01	39,23	47,84	39,43	47,67	39,64	
63	38,79	49,47	39,00	49,31	39,22	49,13	39,43	48,96	39,65	48,79	39,86	48,61	40,07	48,44	40,28	63	39,65	48,79	39,86	48,61	40,07	48,44	40,28	63	39,65	48,79	39,86	48,61	40,07	48,44	40,28	
64	39,40	50,26	39,62	50,09	39,84	49,91	40,06	49,74	40,28	49,56	40,50	49,39	40,70	49,21	40,92	64	40,28	49,56	40,50	49,39	40,70	49,21	40,92	64	40,28	49,56	40,50	49,39	40,70	49,21	40,92	
65	40,02	51,04	40,24	50,87	40,47	50,69	40,69	50,51	40,90	50,34	41,13	50,16	41,35	49,98	41,56	65	40,90	50,34	41,13	50,16	41,35	49,98	41,56	65	40,90	50,34	41,13	50,16	41,35	49,98	41,56	
66	40,64	51,83	40,86	51,66	41,09	51,47	41,31	51,29	41,53	51,11	41,76	50,93	41,98	50,74	42,20	66	41,53	51,11	41,76	50,93	41,98	50,74	42,20	66	41,53	51,11	41,76	50,93	41,98	50,74	42,20	
67	41,25	52,61	41,48	52,44	41,71	52,25	41,94	52,07	42,16	51,88	42,39	51,70	42,62	51,51	42,84	67	42,16	51,88	42,39	51,70	42,62	51,51	42,84	67	42,16	51,88	42,39	51,70	42,62	51,51	42,84	
68	41,87	53,40	42,10	53,22	42,34	53,03	42,56	52,85	42,79	52,66	43,03	52,47	43,25	52,28	43,48	68	42,79	52,66	43,03	52,47	43,25	52,28	43,48	68	42,79	52,66	43,03	52,47	43,25	52,28	43,48	
69	42,48	54,18	42,72	54,00	42,96	53,81	43,19	53,62	43,42	53,43	43,66	53,24	43,89	53,05	44,12	69	43,42	53,62	43,81	53,19	53,43	43,66	53,24	43,89	53,05	44,12	53,24	43,89	53,05	44,12	53,24	
70	43,10	54,97	43,34	54,78	43,58	54,59	43,81	54,40	44,05	54,21	44,29	54,01	44,53	53,82	44,76	70	44,05	54,21	44,29	54,01	44,53	53,82	44,76	70	44,05	54,21	44,29	54,01	44,53	53,82	44,76	
71	43,71	55,76	43,95	55,57	44,20	55,37	44,44	55,18	44,68	54,98	44,92	54,79	45,16	54,59	45,40	71	44,68	54,98	44,92	54,79	45,16	54,59	45,40	71	44,68	54,98	44,92	54,79	45,16	54,59	45,40	
72	44,33	56,54	44,57	56,35	44,82	56,15	45,06	55,96	45,31	55,76	45,56	55,56	45,80	55,36	46,04	72	45,31	55,96	45,56	55,56	45,80	55,36	46,04	72	45,31	55,96	45,56	55,56	45,80	55,36	46,04	
73	44,94	57,33	45,19	57,13	45,45	56,93	45,69	56,73	45,94	56,53	46,19	56,33	46,43	56,13	46,68	73	45,94	56,73	45,94	56,53	46,19	56,33	46,43	73	45,94	56,73	45,94	56,53	46,19	56,33	46,43	
74	45,56	58,11	45,81	57,92	46,07	57,71	46,32	57,51	46,57	57,30	46,82	57,10	47,07	56,90	47,32	74	46,57	57,30	46,82	57,10	47,07	56,90	47,32	74	46,57	57,30	46,82	57,10	47,07	56,90	47,32	
75	46,18	58,90	46,43	58,70	46,69	58,49	46,94	58,29	47,20	58,08	47,46	57,87	47,71	57,60	47,96	75	47,20	58,08	47,46	57,87	47,71	57,60	47,96	75	47,20	58,08	47,46	57,87	47,71	57,60	47,96	
76	46,79	59,68	47,04	59,48	47,31	59,27	47,57	59,06	47,83	58,85	48,09	58,65	48,34	58,43	48,60	76	47,83	58,85	48,09	58,65	48,34	58,43	48,60	76	47,83	58,85	48,09	58,65	48,34	58,43	48,60	
77	47,41	60,47	47,66	60,27	47,94	60,05	48,20	59,84	48,46	59,63	48,72	59,42	48,98	59,20	49,23	77	48,46	59,63	48,72	59,42	48,98	59,20	49,23	77	48,46	59,63	48,72	59,42	48,98	59,20	49,23	
78	48,02	61,25	48,28	61,05	48,56	60,83	48,82	60,62	49,08	60,40	49,36	60,19	49,61	59,97	49,87	78	49,08	60,40	49,36	60,19	49,61	59,97	49,87	78	49,08	60,40	49,36	60,19	49,61	59,97	49,87	
79	48,64	62,04	48,90	61,83	49,36	61,61	49,45	61,39	49,71	61,17	49,99	60,96	50,25	60,94	50,51	79	49,71	61,17	49,99	60,96	50,25	60,94	50,51	79	49,71	61,17	49,99	60,96	50,25	60,94	50,51	
80	49,25	62,83	49,53	62,61	49,80	62,39	50,07	62,17	50,35	61,95	50,62	61,73	50,89	61,51	51,16	80	50,35	61,95	50,62	61,73	50,89	61,51	51,16	80	50,35	61,95	50,62	61,73	50,89	61,51	51,16	
81	49,87	63,61	50,15	63,39	50,42	63,17	50,70	62,95	50,98	62,73	51,25	62,50	51,52	62,28	51,79	81	50,98	62,73	51,25	62,50	51,52	62,28	51,79	81	50,98	62,73	51,25	62,50	51,52	62,28	51,79	
82	50,49	64,40	50,77	64,18	51,05	63,96	51,33	63,73	51,60	63,50	51,88	63,27	52,16	63,05	52,43	82	51,60	63,50	51,88	63,27	52,16	63,05	52,43	82	51,60	63,50	51,88	63,27	52,16	63,05	52,43	
83	51,10	65,18	51,38	64,96	51,67	64,74	51,95	64,50	52,23	64,27	52,52	64,05	52,79	63,81	53,07	83	52,23	64,27	52,52	64,05	52,79	63,81	53,07	83	52,23	64,27	52,52	64,05	52,79	63,81	53,07	
84	51,72	65,97	52,00	65,74	52,29	65,52	52,58	65,28	52,86	65,05	53,15	64,82	53,43	64,58	53,71	84	52,86	65,05	53,15	64,82	53,43	64,58	53,71	84	52,86	65,05	53,15	64,82	53,43	64,58	53,71	
85	52,33	66,75	52,62	66,52	52,92	66,30	53,20	66,06	53,49	65,82	53,78	65,59	54,07	65,35	54,35	85	53,49	65,82	53,78	65,59	54,07	65,35	54,35	85	53,49	65,82	53,78	65,59	54,07	65,35	54,35	
86	52,95	67,54	53,24	67,31	53,54	67,08	53,83	66,83	54,12	66,60	54,42	66,36	54,70	66,12	54,99	86	54,12	66,60	54,42	66,36	54,70	66,12	54,99	86	54,12	66,60	54,42	66,36	54,70	66,12	54,99	
87	53,57	68,32	53,86	68,10	54,16	67,86	54,46	67,61	54,75	67,37	55,05	67,13	55,34	66,89	55,03	87	54,75	67,37	55,05	67,13	55,34	66,89	55,03	87	54,75	67,37	55,05	67,13	55,34	66,89	55,03	
88	54,18	69,11	54,48	68,89	54,79	68,64	55,08	68,39	55,38	68,14	55,68	67,91	55,97	67,66	56,27	88	55,38	68,14	55,68	67,91	55,97	67,66	56,27	88	55,38	68,14	55,68	67,91	55,97	67,66	56,27	
89	54,80	69,90	55,10	69,67	55,41	69,42	55,71	69,17	56,01	68,92	56,32	68,68	56,61	68,43	56,90	89	56,01	68,92	56,32	68,68	56,61	68,43	56,90	89	56,01	68,92	56,32	68,68	56,61	68,43	56,90	
90	55,41	70,68	55,72	70,44	56,03	70,19	56,33	69,94	56,64	69,70	56,94	69,45	57,25	69,20	57,55	90	56,64	69,70	56,94	69,45	57,25	69,20	57,55	90	56,64	69,70	56,94	69,45	57,25	69,20	57,55	
91	56,03	71,46	56,34	71,22	56,63	70,97	56,96	70,71	57,27	70,47	57,58	70,22	57,88	69,97	58,19	91	57,27	70,47	57,58	70,22	57,88	69,97	58,19	91	57,27	70,47	57,58	70,22	57,88	69,97	58,19	
92	56,64	72,25	56,96	72,00	57,21	71,75	57,59	71,50	57,95	71,24	58,21	70,99	58,52	70,73	58,83	92	57,95	71,50	57,95	71,24	58,21	70,99	58,52	92	57,95	71,50	57,95	71,24	58,21	70,99	58,52	
93	57,26	73,03	57,58	72,78	57,90	72,53	58,21	72,28	58,53	72,02	58,84	71,76	59,16	71,50	59,47	93	58,53	72,28	58,84	71,76	59,16	71,50	59,47	93								

TRAVERSE TABLE, 67.

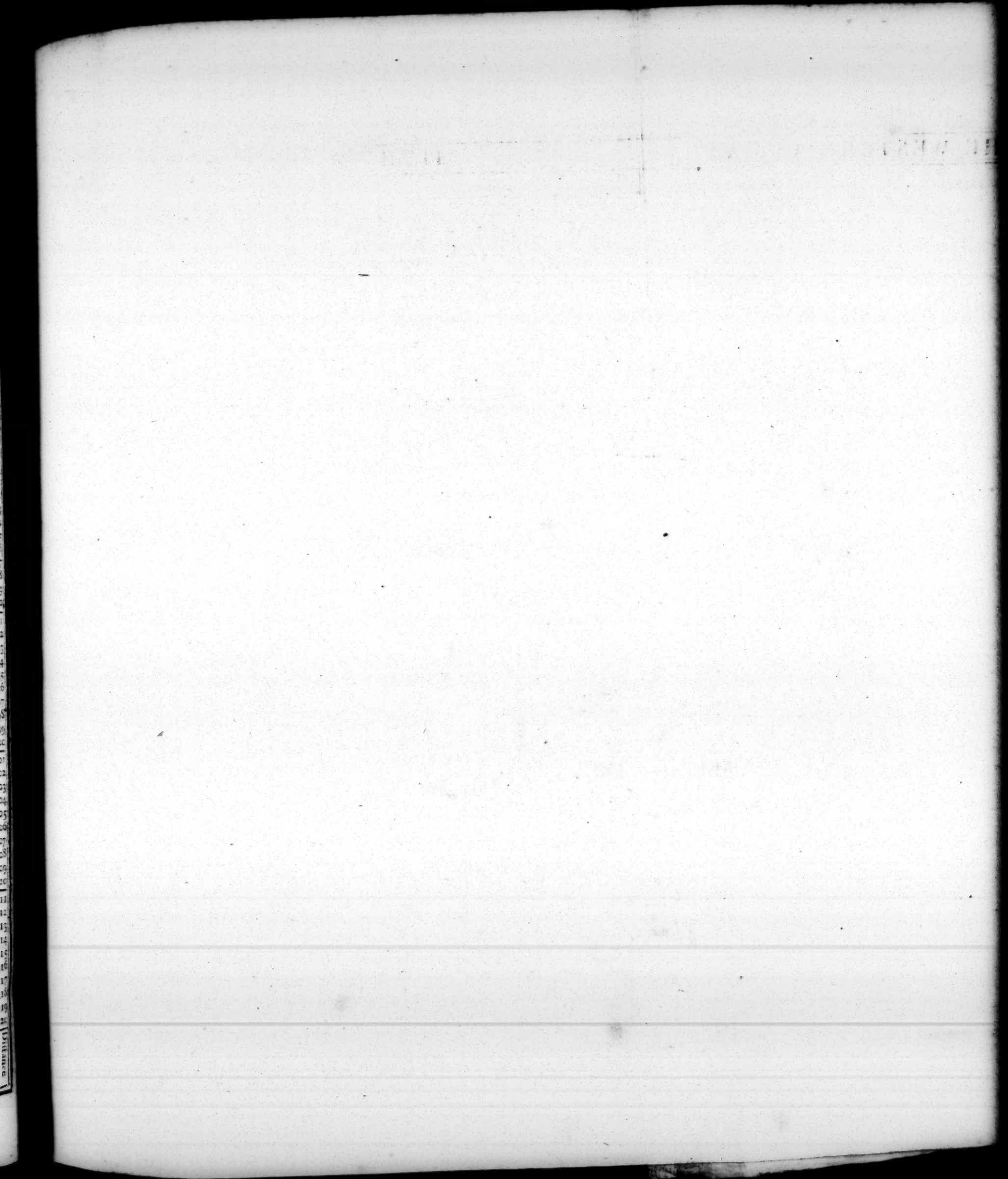
Distance	40 Degrees								41 Degrees							
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	0,77	0,64	0,76	0,65	0,76	0,65	0,76	0,65	0,76	0,66	0,75	0,66	0,75	0,66	0,75	0,67
2	1,53	1,29	1,53	1,29	1,52	1,30	1,52	1,31	1,51	1,31	1,50	1,32	1,50	1,33	1,49	1,50
3	2,30	1,93	2,29	1,94	2,28	1,95	2,27	1,96	2,26	1,97	2,26	1,98	2,25	1,99	2,24	2,00
4	3,06	2,57	3,05	2,58	3,05	2,60	3,03	2,61	3,02	2,62	3,01	2,63	3,00	2,65	2,98	2,66
5	3,83	3,21	3,82	3,23	3,80	3,25	3,78	3,26	3,77	3,28	3,76	3,30	3,75	3,31	3,73	3,32
6	4,60	3,85	4,58	3,88	4,56	3,90	4,55	3,92	4,53	3,94	4,51	3,96	4,49	3,98	4,48	4,00
7	5,36	4,50	5,34	4,52	5,32	4,55	5,30	4,57	5,28	4,59	5,26	4,62	5,24	4,64	5,22	4,66
8	6,13	5,14	6,11	5,17	6,08	5,20	6,06	5,22	6,04	5,25	6,02	5,28	5,99	5,30	5,97	5,33
9	6,89	5,79	6,87	5,82	6,84	5,85	6,82	5,88	6,79	5,91	6,77	5,93	6,74	5,96	6,72	5,99
10	7,66	6,43	7,63	6,46	7,60	6,50	7,58	6,53	7,55	6,56	7,52	6,59	7,49	6,63	7,46	6,66
11	8,43	7,07	8,40	7,11	8,37	7,14	8,33	7,18	8,30	7,22	8,27	7,25	8,24	7,29	8,21	7,33
12	9,19	7,71	9,16	7,75	9,13	7,79	9,09	7,85	9,06	7,87	9,02	7,92	8,99	7,95	8,95	7,99
13	9,96	8,35	9,92	8,40	9,89	8,44	9,85	8,49	9,81	8,53	9,77	8,57	9,74	8,61	9,70	8,66
14	10,72	9,00	10,69	9,05	10,65	9,09	10,61	9,14	10,57	9,18	10,53	9,23	10,49	9,28	10,45	9,50
15	11,49	9,64	11,45	9,69	11,41	9,74	11,37	9,79	11,32	9,84	11,28	9,89	11,24	9,94	11,19	9,99
16	12,26	10,29	12,21	10,34	12,17	10,39	12,12	10,45	12,08	10,50	12,03	10,55	11,98	10,60	11,94	10,66
17	13,02	10,93	12,98	10,98	12,93	11,04	12,88	11,09	12,83	11,15	12,78	11,21	12,73	11,27	12,68	11,33
18	13,79	11,57	13,74	11,63	13,69	11,69	13,64	11,75	13,59	11,81	13,53	11,87	13,48	11,93	13,43	11,99
19	14,55	12,21	14,50	12,28	14,46	12,34	14,40	12,40	14,34	12,47	14,29	12,53	14,23	12,59	14,18	12,64
20	15,32	12,86	15,27	12,92	15,21	12,99	15,15	13,06	15,09	13,12	15,04	13,19	14,98	13,25	14,92	13,30
21	16,09	13,50	16,03	13,57	15,97	13,64	15,91	13,71	15,85	13,78	15,79	13,85	15,73	13,92	15,67	13,98
22	16,85	14,14	16,79	14,21	16,73	14,29	16,67	14,36	16,60	14,43	16,54	14,51	16,48	14,58	16,41	14,56
23	17,62	14,79	17,55	14,86	17,49	14,94	17,43	15,01	17,36	15,09	17,30	15,16	17,23	15,24	17,16	15,31
24	18,39	15,43	18,32	15,51	18,25	15,59	18,18	15,67	18,11	15,75	18,05	15,82	17,98	15,90	17,91	15,98
25	19,15	16,07	19,08	16,15	19,01	16,23	18,94	16,31	18,87	16,39	18,80	16,48	18,73	16,57	18,65	16,64
26	19,92	16,71	19,84	16,80	19,77	16,88	19,70	16,97	19,61	17,05	19,55	17,14	19,47	17,23	19,40	17,31
27	20,68	17,36	20,61	17,44	20,53	17,53	20,46	17,63	20,38	17,70	20,30	17,80	20,22	17,86	20,14	17,88
28	21,45	18,00	21,37	18,09	21,29	18,18	21,22	18,28	21,13	18,36	21,05	18,46	20,97	18,55	20,89	18,96
29	22,22	18,64	22,13	18,74	22,05	18,83	21,97	18,93	21,89	19,02	21,81	19,12	21,72	19,22	21,64	19,31
30	22,98	19,28	22,90	19,38	22,81	19,48	22,73	19,58	22,64	19,68	22,56	19,78	22,47	19,88	22,38	19,90
31	23,75	19,93	23,66	20,03	23,57	20,13	23,49	20,24	23,39	20,34	23,31	20,44	23,22	20,54	23,13	20,64
32	24,51	20,57	24,42	20,68	24,33	20,78	24,24	20,89	24,15	20,99	24,06	21,10	23,97	21,21	23,87	21,31
33	25,28	21,21	25,19	21,32	25,09	21,48	25,00	21,54	24,91	21,65	24,81	21,76	24,72	21,86	24,62	21,97
34	26,05	21,86	25,95	21,97	25,85	22,08	25,76	22,20	25,66	22,31	25,56	22,42	25,47	22,53	25,37	22,64
35	26,81	22,50	26,71	22,61	26,61	22,73	26,52	22,85	26,42	22,96	26,32	23,08	26,21	23,19	26,11	23,31
36	27,58	23,14	27,48	23,26	27,37	23,38	27,28	23,50	27,17	23,62	27,07	23,74	26,96	23,86	26,86	23,97
37	28,34	23,79	28,24	23,91	28,13	24,03	28,03	24,15	27,93	24,37	27,82	24,39	27,71	24,52	27,60	24,64
38	29,11	24,43	29,00	24,55	28,89	24,68	28,79	24,81	28,68	25,03	28,57	25,05	28,46	25,18	28,35	25,31
39	29,88	25,07	29,76	25,20	29,65	25,33	29,55	25,46	29,44	25,65	29,32	25,71	29,21	25,85	29,10	25,97
40	30,64	25,71	30,53	25,85	30,42	25,98	30,30	26,11	30,19	26,24	30,07	26,37	29,96	26,51	29,84	26,64
41	31,41	26,36	31,29	26,49	31,18	26,63	31,06	26,76	30,94	26,90	30,83	27,03	30,71	27,17	30,59	27,30
42	32,17	26,99	32,06	27,14	31,94	27,28	31,81	27,42	31,69	27,55	31,58	27,69	31,46	27,83	31,33	27,97
43	32,94	27,64	32,82	27,78	32,70	27,93	32,58	28,07	32,35	28,21	32,33	28,35	32,20	28,49	32,08	28,66
44	33,71	28,28	33,58	28,43	33,46	28,57	33,34	28,72	33,11	28,87	33,08	29,01	32,94	29,16	32,81	29,31
45	34,47	28,93	34,34	29,08	34,22	29,22	34,09	29,38	33,86	29,52	33,83	29,67	33,69	29,82	33,55	29,97
46	35,24	29,57	35,11	29,74	34,98	29,87	34,85	30,03	34,62	30,18	34,59	30,33	34,44	30,48	34,32	30,63
47	36,00	30,21	35,87	30,37	35,74	30,52	35,61	30,68	35,37	30,83	35,34	30,99	35,19	31,15	35,06	31,30
48	36,77	30,86	36,63	31,01	36,50	31,17	36,37	31,33	36,13	31,49	36,09	31,65	35,94	31,81	35,81	31,96
49	37,54	31,50	37,40	31,66	37,26	31,82	37,13	31,99	36,88	32,15	36,84	32,31	36,69	32,47	36,56	32,63
50	38,30	32,14	38,16	32,31	38,02	32,47	37,88	32,64	37,74	32,80	37,59	32,97	37,45	33,13	37,30	33,29
51	39,07	32,78	38,93	32,95	38,78	33,12	38,64	33,29	38,49	33,46	38,24	33,63	38,20	33,79	38,05	33,96
52	39,83	33,43	39,69	33,60	39,54	33,77	39,40	33,94	39,25	34,12	39,00	34,29	38,95	34,46	38,80	34,63
53	40,60	34,07	40,45	34,24	40,30	34,42	40,15	34,60	40,00	34,77	39,75	34,95	39,70	35,12	39,54	35,29
54	41,37	34,71	41,21	34,89	41,06	35,07	40,91	35,25	40,76	35,43	40,50	35,60	40,44	35,78	40,29	35,96
55	42,13	35,36	41,98	35,54	41,82	35,72	41,67	35,90	41,51	36,08	41,25	36,26	41,19	36,45	41,03	36,62
56	42,90	36,00	42,74	36,18	42,58	36,37	42,43	36,56	42,27	36,74	42,00	36,92	41,94	37,11	41,78	37,29
57	43,66	36,64	43,50	36,83	43,34	37,02	43,19	37,21	43,02	37,40	42,76	37,58	42,69	37,77	42,53	37,90
58	44,43	37,28	44,27	37,47	44,10	37,67	43,95	37,86	43,77	38,05	43,51	38,24	43,44	38,44	43,27	38,62
59	45,20	37,93	45,03	38,12	44,86	38,31	44,70	38,52	44,53	38,71	44,26	38,90	44,19	39,10	44,02	39,29
60	45,96	38,57	45,79	38,77	45,63	38,97	45,45	39,17	45,28	39,36	45,01	39,56	44,94	39,76	44,76	39,95
Distance	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
	50 Degrees		49 Degrees		1,15		48 Degrees		1,11							

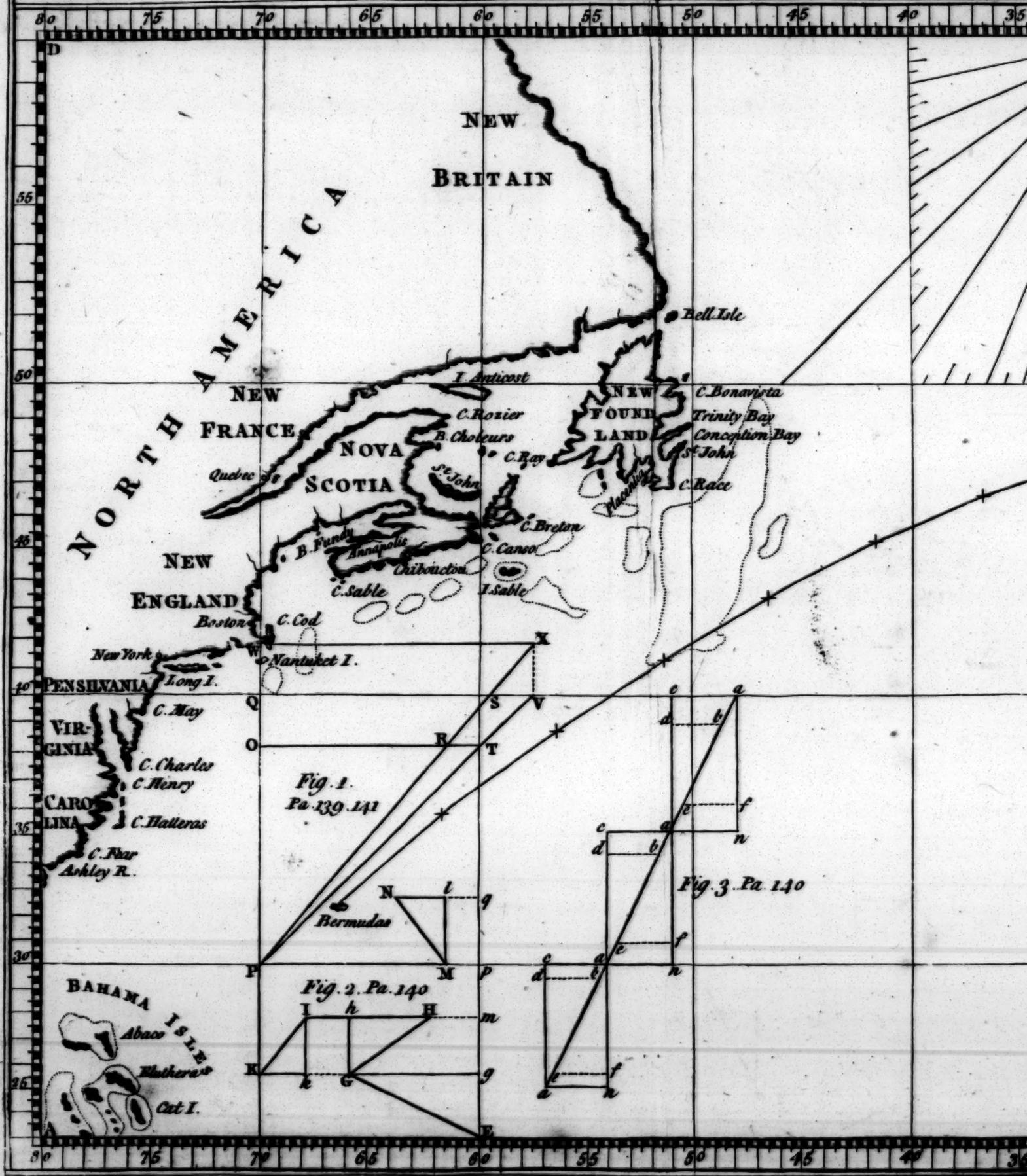
40 Degrees										,84		41 Degrees										,87		Distance								
0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.										
Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.									
61	40,56	39,41	46,35	39,62	46,21	39,8	46,04	40,02	45,86	40,16	45,69	40,42	45,51	40,62	45,34	61	40,56	39,41	46,35	39,62	46,21	39,8	46,04		40,02	45,86	40,16	45,69	40,42	45,51	40,62	45,34
62	40,57	39,40	46,36	39,63	46,22	39,9	46,05	40,03	45,87	40,17	45,70	40,43	45,52	40,63	45,35	62	40,57	39,40	46,36	39,63	46,22	39,9	46,05		40,03	45,87	40,17	45,70	40,43	45,52	40,63	45,35
63	40,58	39,39	46,37	39,64	46,23	40,0	46,06	40,04	45,88	40,18	45,71	40,44	45,53	40,64	45,36	63	40,58	39,39	46,37	39,64	46,23	40,0	46,06	40,04	45,88	40,18	45,71	40,44	45,53	40,64	45,36	
64	40,59	39,38	46,38	39,65	46,24	40,1	46,07	40,05	45,89	40,19	45,72	40,45	45,54	40,65	45,37	64	40,59	39,38	46,38	39,65	46,24	40,1	46,07	40,05	45,89	40,19	45,72	40,45	45,54	40,65	45,37	
65	40,60	39,37	46,39	39,66	46,25	40,2	46,08	40,06	45,90	40,20	45,73	40,46	45,55	40,66	45,38	65	40,60	39,37	46,39	39,66	46,25	40,2	46,08	40,06	45,90	40,20	45,73	40,46	45,55	40,66	45,38	
66	40,61	39,36	46,40	39,67	46,26	40,3	46,09	40,07	45,91	40,21	45,74	40,47	45,56	40,67	45,39	66	40,61	39,36	46,40	39,67	46,26	40,3	46,09	40,07	45,91	40,21	45,74	40,47	45,56	40,67	45,39	
67	40,62	39,35	46,41	39,68	46,27	40,4	46,10	40,08	45,92	40,22	45,75	40,48	45,57	40,68	45,40	67	40,62	39,35	46,41	39,68	46,27	40,4	46,10	40,08	45,92	40,22	45,75	40,48	45,57	40,68	45,40	
68	40,63	39,34	46,42	39,69	46,28	40,5	46,11	40,09	45,93	40,23	45,76	40,49	45,58	40,69	45,41	68	40,63	39,34	46,42	39,69	46,28	40,5	46,11	40,09	45,93	40,23	45,76	40,49	45,58	40,69	45,41	
69	40,64	39,33	46,43	39,70	46,29	40,6	46,12	40,10	45,94	40,24	45,77	40,50	45,59	40,70	45,42	69	40,64	39,33	46,43	39,70	46,29	40,6	46,12	40,10	45,94	40,24	45,77	40,50	45,59	40,70	45,42	
70	40,65	39,32	46,44	39,71	46,30	40,7	46,13	40,11	45,95	40,25	45,78	40,51	45,60	40,71	45,43	70	40,65	39,32	46,44	39,71	46,30	40,7	46,13	40,11	45,95	40,25	45,78	40,51	45,60	40,71	45,43	
71	40,66	39,31	46,45	39,72	46,31	40,8	46,14	40,12	45,96	40,26	45,79	40,52	45,61	40,72	45,44	71	40,66	39,31	46,45	39,72	46,31	40,8	46,14	40,12	45,96	40,26	45,79	40,52	45,61	40,72	45,44	
72	40,67	39,30	46,46	39,73	46,32	40,9	46,15	40,13	45,97	40,27	45,80	40,53	45,62	40,73	45,45	72	40,67	39,30	46,46	39,73	46,32	40,9	46,15	40,13	45,97	40,27	45,80	40,53	45,62	40,73	45,45	
73	40,68	39,29	46,47	39,74	46,33	41,0	46,16	40,14	45,98	40,28	45,81	40,54	45,63	40,74	45,46	73	40,68	39,29	46,47	39,74	46,33	41,0	46,16	40,14	45,98	40,28	45,81	40,54	45,63	40,74	45,46	
74	40,69	39,28	46,48	39,75	46,34	41,1	46,17	40,15	45,99	40,29	45,82	40,55	45,64	40,75	45,47	74	40,69	39,28	46,48	39,75	46,34	41,1	46,17	40,15	45,99	40,29	45,82	40,55	45,64	40,75	45,47	
75	40,70	39,27	46,49	39,76	46,35	41,2	46,18	40,16	46,00	40,30	45,83	40,56	45,65	40,76	45,48	75	40,70	39,27	46,49	39,76	46,35	41,2	46,18	40,16	46,00	40,30	45,83	40,56	45,65	40,76	45,48	
76	40,71	39,26	46,50	39,77	46,36	41,3	46,19	40,17	46,01	40,31	45,84	40,57	45,66	40,77	45,49	76	40,71	39,26	46,50	39,77	46,36	41,3	46,19	40,17	46,01	40,31	45,84	40,57	45,66	40,77	45,49	
77	40,72	39,25	46,51	39,78	46,37	41,4	46,20	40,18	46,02	40,32	45,85	40,58	45,67	40,78	45,50	77	40,72	39,25	46,51	39,78	46,37	41,4	46,20	40,18	46,02	40,32	45,85	40,58	45,67	40,78	45,50	
78	40,73	39,24	46,52	39,79	46,38	41,5	46,21	40,19	46,03	40,33	45,86	40,59	45,68	40,79	45,51	78	40,73	39,24	46,52	39,79	46,38	41,5	46,21	40,19	46,03	40,33	45,86	40,59	45,68	40,79	45,51	
79	40,74	39,23	46,53	39,80	46,39	41,6	46,22	40,20	46,04	40,34	45,87	40,60	45,69	40,80	45,52	79	40,74	39,23	46,53	39,80	46,39	41,6	46,22	40,20	46,04	40,34	45,87	40,60	45,69	40,80	45,52	
80	40,75	39,22	46,54	39,81	46,40	41,7	46,23	40,21	46,05	40,35	45,88	40,61	45,70	40,81	45,53	80	40,75	39,22	46,54	39,81	46,40	41,7	46,23	40,21	46,05	40,35	45,88	40,61	45,70	40,81	45,53	
81	40,76	39,21	46,55	39,82	46,41	41,8	46,24	40,22	46,06	40,36	45,89	40,62	45,71	40,82	45,54	81	40,76	39,21	46,55	39,82	46,41	41,8	46,24	40,22	46,06	40,36	45,89	40,62	45,71	40,82	45,54	
82	40,77	39,20	46,56	39,83	46,42	41,9	46,25	40,23	46,07	40,37	45,90	40,63	45,72	40,83	45,55	82	40,77	39,20	46,56	39,83	46,42	41,9	46,25	40,23	46,07	40,37	45,90	40,63	45,72	40,83	45,55	
83	40,78	39,19	46,57	39,84	46,43	42,0	46,26	40,24	46,08	40,38	45,91	40,64	45,73	40,84	45,56	83	40,78	39,19	46,57	39,84	46,43	42,0	46,26	40,24	46,08	40,38	45,91	40,64	45,73	40,84	45,56	
84	40,79	39,18	46,58	39,85	46,44	42,1	46,27	40,25	46,09	40,39	45,92	40,65	45,74	40,85	45,57	84	40,79	39,18	46,58	39,85	46,44	42,1	46,27	40,25	46,09	40,39	45,92	40,65	45,74	40,85	45,57	
85	40,80	39,17	46,59	39,86	46,45	42,2	46,28	40,26	46,10	40,40	45,93	40,66	45,75	40,86	45,58	85	40,80	39,17	46,59	39,86	46,45	42,2	46,28	40,26	46,10	40,40	45,93	40,66	45,75	40,86	45,58	
86	40,81	39,16	46,60	39,87	46,46	42,3	46,29	40,27	46,11	40,41	45,94	40,67	45,76	40,87	45,59	86	40,81	39,16	46,60	39,87	46,46	42,3	46,29	40,27	46,11	40,41	45,94	40,67	45,76	40,87	45,59	
87	40,82	39,15	46,61	39,88	46,47	42,4	46,30	40,28	46,12	40,42	45,95	40,68	45,77	40,88	45,60	87	40,82	39,15	46,61	39,88	46,47	42,4	46,30	40,28	46,12	40,42	45,95	40,68	45,77	40,88	45,60	
88	40,83	39,14	46,62	39,89	46,48	42,5	46,31	40,29	46,13	40,43	45,96	40,69	45,78	40,89	45,61	88	40,83	39,14	46,62	39,89	46,48	42,5	46,31	40,29	46,13	40,43	45,96	40,69	45,78	40,89	45,61	
89	40,84	39,13	46,63	39,90	46,49	42,6	46,32	40,30	46,14	40,44	45,97	40,70	45,79	40,90	45,62	89	40,84	39,13	46,63	39,90	46,49	42,6	46,32	40,30	46,14	40,44	45,97	40,70	45,79	40,90	45,62	
90	40,85	39,12	46,64	39,91	46,50	42,7	46,33	40,31	46,15	40,45	45,98	40,71	45,80	40,91	45,63	90	40,85	39,12	46,64	39,91	46,50	42,7	46,33	40,31	46,15	40,45	45,98	40,71	45,80	40,91	45,63	
91	40,86	39,11	46,65	39,92	46,51	42,8	46,34	40,32	46,16	40,46	45,99	40,72	45,81	40,92	45,64	91	40,86	39,11	46,65	39,92	46,51	42,8	46,34	40,32	46,16	40,46	45,99	40,72	45,81	40,92	45,64	
92	40,87	39,10	46,66	39,93	46,52	42,9	46,35	40,33	46,17	40,47	46,00	40,73	45,82	40,93	45,65	92	40,87	39,10	46,66	39,93	46,52	42,9	46,35	40,33	46,17	40,47	46,00	40,73	45,82	40,93	45,65	
93	40,88	39,09	46,67	39,94	46,53	43,0	46,36	40,34	46,18	40,48	46,01	40,74	45,83	40,94	45,66	93	40,88	39,09	46,67	39,94	46,53	43,0	46,36	40,34	46,18	40,48	46,01	40,74	45,83	40,94	45,66	
94	40,89	39,08	46,68	39,95	46,54	43,1	46,37	40,35	46,19	40,49	46,02	40,75	45,84	40,95	45,67	94	40,89	39,08	46,68	39,95	46,54	43,1	46,37	40,35	46,19	40,49	46,02	40,75	45,84	40,95	45,67	
95	40,90	39,07	46,69	39,96	46,55	43,2	46,38	40,36	46,20	40,50	46,03	40,76	45,85	40,96	45,68	95	40,90	39,07	46,69	39,96	46,55	43,2	46,38	40,36	46,20	40,50	46,03	40,76	45,85	40,96	45,68	
96	40,91	39,06	46,70	39,97	46,56	43,3	46,39	40,37	46,21	40,51	46,04	40,77	45,86	40,97	45,69	96	40,91	39,06	46,70	39,97	46,56	43,3	46,39	40,37	46,21	40,51	46,04	40,77	45,86	40,97	45,69	
97	40,92	39,05	46,71	39,98	46,57	43,4	46,40	40,38	46,2																							

Distance	42 Degrees								43 Degrees								Distance
	0 Min.		15 Min.		30 Min.		45 Min.		0 Min.		15 Min.		30 Min.		45 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Lat.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0,74	0,67	0,74	0,67	0,74	0,68	0,73	0,68	0,73	0,68	0,73	0,68	0,72	0,69	0,72	0,69	1
2	1,49	1,34	1,48	1,34	1,47	1,35	1,47	1,36	1,46	1,36	1,46	1,37	1,45	1,38	1,44	1,38	2
3	2,23	2,07	2,22	2,02	2,21	2,03	2,20	2,04	2,19	2,05	2,18	2,06	2,18	2,06	2,17	2,07	3
4	2,97	2,68	2,96	2,69	2,95	2,70	2,94	2,71	2,92	2,72	2,91	2,74	2,90	2,75	2,89	2,77	4
5	3,72	3,35	3,70	3,36	3,69	3,38	3,67	3,39	3,66	3,41	3,64	3,43	3,63	3,44	3,61	3,46	5
6	4,46	4,01	4,44	4,03	4,42	4,05	4,41	4,07	4,39	4,09	4,37	4,11	4,35	4,13	4,33	4,15	6
7	5,20	4,68	5,18	4,71	5,16	4,73	5,14	4,75	5,12	4,77	5,10	4,80	5,08	4,82	5,06	4,84	7
8	5,94	5,35	5,92	5,38	5,90	5,40	5,87	5,43	5,85	5,46	5,83	5,48	5,80	5,51	5,78	5,53	8
9	6,69	6,02	6,66	6,05	6,64	6,08	6,61	6,11	6,58	6,14	6,55	6,17	6,53	6,19	6,50	6,22	9
10	7,43	6,67	7,40	6,72	7,37	6,76	7,34	6,79	7,31	6,82	7,28	6,85	7,25	6,88	7,22	6,91	10
11	8,17	7,36	8,14	7,40	8,11	7,43	8,08	7,47	8,04	7,50	8,01	7,54	7,98	7,57	7,95	7,61	11
12	8,92	8,03	8,88	8,07	8,85	8,11	8,81	8,15	8,78	8,18	8,74	8,22	8,70	8,26	8,67	8,30	12
13	9,66	8,70	9,62	8,74	9,58	8,78	9,55	8,82	9,51	8,87	9,47	8,91	9,43	8,95	9,39	8,99	13
14	10,40	9,37	10,36	9,41	10,32	9,46	10,28	9,50	10,24	9,55	10,20	9,59	10,15	9,64	10,11	9,68	14
15	11,15	10,04	11,10	10,08	11,06	10,13	11,01	10,18	10,97	10,23	10,92	10,28	10,88	10,32	10,83	10,37	15
16	11,89	10,71	11,84	10,76	11,79	10,81	11,75	10,86	11,70	10,91	11,65	10,96	11,60	11,01	11,56	11,07	16
17	12,63	11,37	12,58	11,43	12,53	11,49	12,48	11,54	12,43	11,59	12,38	11,65	12,33	11,70	12,28	11,76	17
18	13,38	12,04	13,32	12,10	13,27	12,16	13,22	12,22	13,16	12,28	13,11	12,33	13,05	12,39	13,00	12,45	18
19	14,12	12,71	14,06	12,77	14,01	12,84	13,95	12,90	13,89	12,96	13,84	13,02	13,78	13,08	13,72	13,14	19
20	14,86	13,38	14,80	13,45	14,75	13,51	14,69	13,58	14,63	13,64	14,57	13,70	14,51	13,77	14,45	13,83	20
21	15,61	14,05	15,54	14,12	15,48	14,19	15,42	14,25	15,36	14,32	15,29	14,39	15,23	14,45	15,17	14,52	21
22	16,35	14,72	16,28	14,79	16,22	14,86	16,15	14,93	16,09	15,00	16,02	15,07	15,96	15,14	15,89	15,21	22
23	17,09	15,39	17,02	15,46	16,96	15,54	16,89	15,61	16,82	15,69	16,75	15,76	16,68	15,83	16,61	15,91	23
24	17,83	16,00	17,76	16,13	17,79	16,22	17,62	16,29	17,55	16,37	17,48	16,44	17,41	16,52	17,33	16,60	24
25	18,58	16,73	18,50	16,80	18,43	16,89	18,36	16,97	18,28	17,05	18,21	17,13	18,13	17,21	18,06	17,29	25
26	19,32	17,40	19,24	17,47	19,17	17,57	19,09	17,65	19,01	17,73	18,94	17,81	18,86	17,89	18,77	17,98	26
27	20,06	18,07	19,98	18,15	19,91	18,24	19,82	18,33	19,74	18,41	19,66	18,50	19,58	18,58	19,50	18,67	27
28	20,81	18,73	20,72	18,82	20,64	18,92	20,56	19,01	20,47	19,10	20,39	19,18	20,31	19,27	20,22	19,37	28
29	21,55	19,40	21,46	19,49	21,38	19,60	21,29	19,69	21,21	19,78	21,12	19,87	21,03	19,96	20,94	20,06	29
30	22,29	20,07	22,21	20,17	22,12	20,27	22,03	20,36	21,94	20,46	21,85	20,55	21,76	20,65	21,67	20,74	30
31	23,04	20,74	22,95	20,84	22,85	20,94	22,76	21,04	22,67	21,14	22,58	21,24	22,49	21,34	22,39	21,44	31
32	23,78	21,41	23,69	21,51	23,59	21,62	23,50	21,72	23,40	21,82	23,30	21,92	23,21	22,03	23,11	22,13	32
33	24,52	22,08	24,43	22,19	24,33	22,30	24,23	22,40	24,13	22,51	24,02	22,61	23,94	22,71	23,84	22,82	33
34	25,27	22,75	25,17	22,86	25,07	22,96	24,97	23,08	24,86	23,19	24,75	23,29	24,66	23,40	24,56	23,51	34
35	26,01	23,42	25,91	23,53	25,80	23,64	25,70	23,76	25,60	23,87	25,48	23,98	25,39	24,09	25,28	24,20	35
36	26,75	24,09	26,65	24,20	26,54	24,31	26,43	24,44	26,32	24,55	26,21	24,66	26,11	24,78	26,00	24,90	36
37	27,49	24,76	27,39	24,87	27,28	24,99	27,17	25,12	27,06	25,23	26,94	25,35	26,84	25,47	26,73	25,90	37
38	28,24	25,43	28,13	25,55	28,01	25,67	27,90	25,79	27,79	25,91	27,66	26,03	27,56	26,16	27,44	26,28	38
39	28,98	26,09	28,87	26,22	28,75	26,34	28,64	26,47	28,52	26,60	28,39	26,72	28,29	26,84	28,18	26,97	39
40	29,73	26,76	29,61	26,89	29,49	27,02	29,37	27,15	29,25	27,28	29,13	27,41	29,01	27,53	28,89	27,66	40
41	30,47	27,43	30,35	27,57	30,23	27,70	30,11	27,83	29,98	27,96	29,86	28,09	29,74	28,22	29,62	28,35	41
42	31,21	28,10	31,09	28,24	30,96	28,38	30,84	28,51	30,72	28,64	30,59	28,78	30,46	28,91	30,34	29,04	42
43	31,95	28,77	31,83	28,91	31,69	29,05	31,57	29,19	31,45	29,33	31,32	29,46	31,19	29,60	31,06	29,74	43
44	32,70	29,44	32,57	29,58	32,43	29,73	32,31	29,87	32,18	30,01	32,05	30,15	31,91	30,29	31,78	30,43	44
45	33,44	30,10	33,31	30,25	33,17	30,40	33,04	30,55	32,91	30,69	32,77	30,83	32,64	30,97	32,50	31,12	45
46	34,18	30,77	34,05	30,93	33,90	31,08	33,78	31,23	33,64	31,37	33,50	31,52	33,36	31,66	33,23	31,82	46
47	34,93	31,44	34,79	31,60	34,64	31,76	34,51	31,90	34,37	32,05	34,23	32,20	34,09	32,35	33,95	32,51	47
48	35,67	32,11	35,53	32,27	35,38	32,43	35,24	32,58	35,10	32,74	34,96	32,89	34,82	33,04	34,67	33,20	48
49	36,41	32,78	36,27	32,94	36,11	33,11	35,98	33,26	35,83	33,42	35,69	33,57	35,54	33,73	35,39	33,90	49
50	37,16	33,46	37,01	33,62	36,86	33,78	36,72	33,94	36,57	34,10	36,42	34,26	36,27	34,42	36,12	34,58	50
51	37,90	34,13	37,75	34,29	37,60	34,46	37,45	34,62	37,30	34,78	37,15	34,94	36,99	35,11	36,84	35,27	51
52	38,64	34,79	38,49	34,96	38,34	35,13	38,18	35,30	38,03	35,46	37,87	35,63	37,72	35,79	37,56	35,96	52
53	39,39	35,46	39,23	35,63	39,07	35,81	38,92	35,98	38,76	36,15	38,60	36,31	38,44	36,48	38,28	36,65	53
54	40,13	36,13	39,97	36,31	39,81	36,48	39,65	36,66	39,49	36,83	39,33	37,00	39,17	37,17	39,01	37,34	54
55	40,87	36,80	40,71	36,98	40,55	37,16	40,39	37,33	40,22	37,51	40,06	37,68	39,89	37,86	39,73	38,04	55
56	41,61	37,47	41,45	37,65	41,29	37,84	41,12	38,01	40,95	38,19	40,79	38,37	40,62	38,55	40,45	38,73	56
57	42,36	38,14	42,19	38,32	42,02	38,51	41,85	38,69	41,68	38,87	41,51	39,05	41,34	39,23	41,16	39,43	57
58	43,10	38,81	42,93	38,99	42,76	39,19	42,59	39,87	42,42	39,56	42,24	39,74	42,07	39,92	41,89	40,11	58
59	43,84	39,48	43,67	39,67	43,50	39,86	43,32	40,05	43,15	40,24	42,97	40,42	42,78	40,61	42,62	40,80	59
60	44,59	40,15	44,41	40,34	44,24	40,53	44,06	40,73	43,88	40,92	43,70	41,11	43,52	41,30	43,34	41,49	60
Distance	0 Min.		45 Min.		30 Min.		15 Min.		0 Min.		45 Min.		30 Min.		15 Min.		Distance
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	48 Deg.		47 Degrees		46 Degrees		45 Degrees		44 Degrees		43 Degrees		42 Degrees		41 Degrees		

VOL. II.

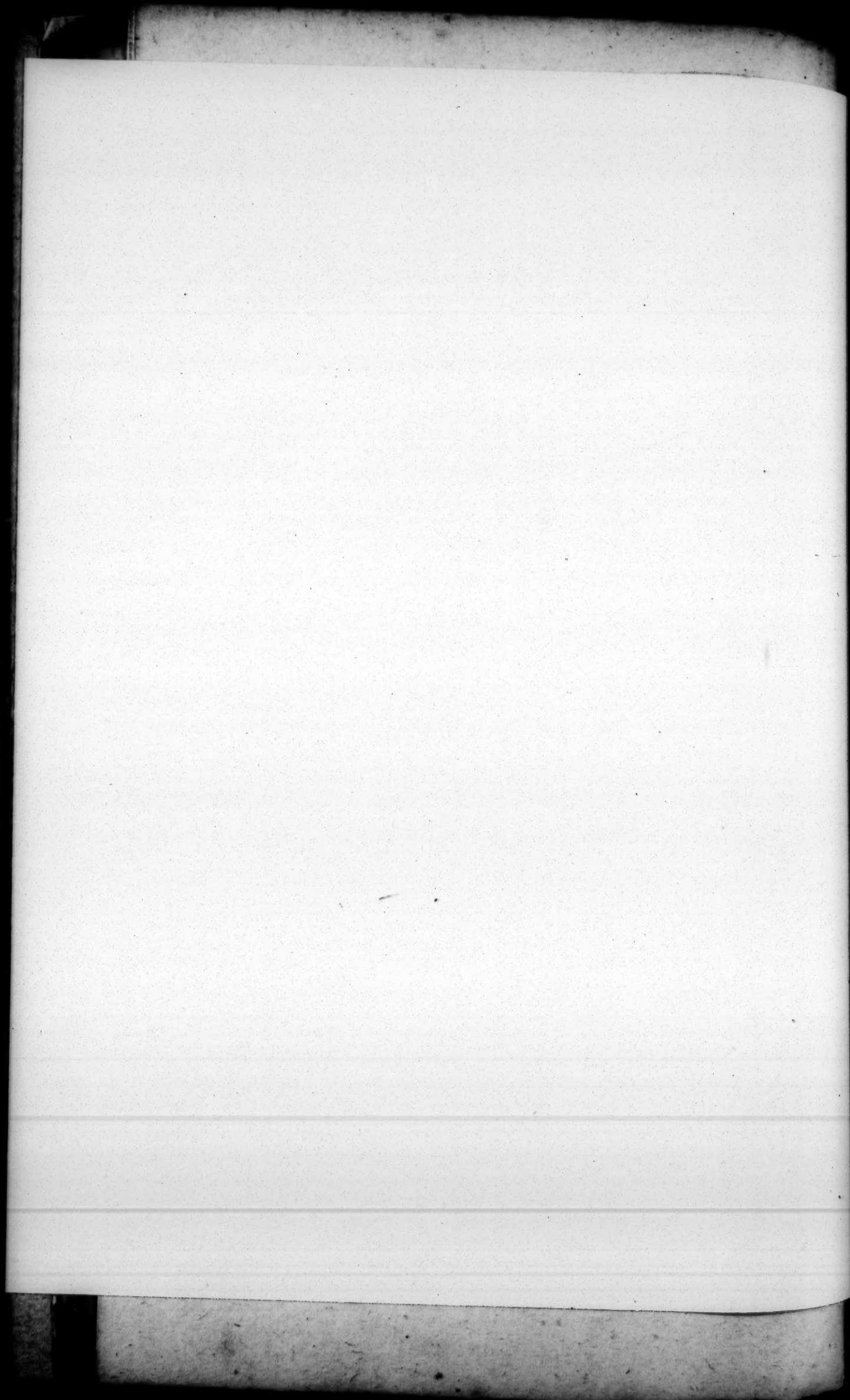
Distance	44 Degrees						,97 45 Deg.		44 Degrees						,97 45 Deg.		Distance
	0 Min.		20 Min.		40 Min.		0 Min.		0 Min.		20 Min.		40 Min.		0 Min.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0,72	0,69	0,72	0,70	0,71	0,70	0,71	0,71	43,88	42,37	43,63	42,63	43,38	42,88	43,13	42,13	61
2	1,44	1,39	1,43	1,40	1,42	1,41	1,41	1,41	44,60	43,07	44,35	43,33	44,09	43,58	43,84	42,84	62
3	2,16	2,08	2,15	2,10	2,13	2,11	2,12	2,12	45,32	43,76	45,06	44,03	44,81	44,29	44,55	44,53	63
4	2,88	2,78	2,86	2,79	2,84	2,81	2,83	2,83	46,04	44,46	45,78	44,73	45,52	44,99	45,25	45,25	64
5	3,60	3,47	3,58	3,49	3,56	3,51	3,53	3,53	46,75	45,15	46,49	45,42	46,23	45,69	45,95	45,95	65
6	4,32	4,17	4,29	4,19	4,27	4,22	4,24	4,24	47,47	45,85	47,21	46,12	46,94	46,40	46,66	46,66	66
7	5,03	4,86	5,01	4,89	4,98	4,92	4,95	4,95	48,19	46,54	47,92	46,82	47,55	47,01	47,27	47,27	67
8	5,75	5,56	5,72	5,59	5,69	5,62	5,66	5,66	48,91	47,24	48,64	47,52	48,36	47,81	48,07	47,81	68
9	6,47	6,25	6,44	6,40	6,40	6,33	6,36	6,36	49,63	48,95	49,35	48,22	49,08	48,53	48,79	48,53	69
10	7,19	6,95	7,15	6,99	7,11	7,03	7,07	7,07	50,35	48,63	50,07	48,91	49,78	49,23	49,49	49,23	70
11	7,91	7,64	7,87	7,69	7,82	7,73	7,78	7,78	51,07	49,32	50,78	49,62	50,43	49,91	50,17	50,17	71
12	8,63	8,34	8,58	8,39	8,53	8,44	8,49	8,49	51,79	50,02	51,50	50,32	51,21	50,61	50,91	50,91	72
13	9,35	9,03	9,30	9,08	9,25	9,14	9,19	9,19	52,51	50,71	52,21	51,01	51,91	51,32	51,62	51,62	73
14	10,07	9,73	10,01	9,78	9,96	9,84	9,90	9,90	53,23	51,41	52,93	51,71	52,63	52,02	52,32	52,32	74
15	10,79	10,42	10,73	10,48	10,67	10,54	10,61	10,61	54,25	52,10	53,64	52,41	53,34	52,72	53,03	53,03	75
16	11,51	11,12	11,44	11,18	11,38	11,25	11,31	11,31	54,97	52,80	54,36	53,11	54,05	53,44	53,74	53,74	76
17	12,23	11,81	12,16	12,88	12,09	11,95	12,02	12,02	55,69	53,49	55,07	53,81	54,76	54,13	54,45	54,45	77
18	12,94	12,51	12,87	12,57	12,80	12,65	12,73	12,73	56,41	54,19	55,79	54,51	55,47	54,83	55,15	55,15	78
19	13,65	13,20	13,59	13,27	13,51	13,36	13,43	13,43	57,12	54,88	56,50	55,21	56,18	55,53	55,86	55,86	79
20	14,39	13,89	14,31	13,98	14,22	14,06	14,14	14,14	57,55	55,57	57,22	55,91	56,90	56,24	56,57	56,57	80
21	15,11	14,59	15,02	14,68	14,93	14,76	14,85	14,85	58,27	56,27	57,94	56,60	57,61	56,94	57,28	57,28	81
22	15,82	15,28	15,74	15,37	15,65	15,46	15,56	15,56	58,98	56,96	58,65	57,30	58,37	57,64	57,98	57,98	82
23	16,54	15,98	16,45	16,07	16,36	16,17	16,26	16,26	59,70	57,66	59,37	58,00	59,03	58,35	58,69	58,69	83
24	17,26	16,67	17,17	16,77	17,07	16,87	16,97	16,97	60,42	58,35	60,08	58,70	59,74	59,05	59,40	59,40	84
25	17,98	17,37	17,88	17,47	17,78	17,57	17,68	17,68	61,14	59,05	60,80	59,40	60,45	59,75	60,10	60,10	85
26	18,70	18,06	18,60	18,17	18,49	18,28	18,38	18,38	61,86	59,74	61,51	60,10	61,16	60,45	60,81	60,81	86
27	19,42	18,76	19,31	18,87	19,20	18,98	19,09	19,09	62,58	60,44	62,23	60,80	61,87	61,16	61,52	61,52	87
28	20,14	19,45	20,03	19,57	19,91	19,68	19,80	19,80	63,30	61,13	62,94	61,50	62,58	61,86	62,22	62,22	88
29	20,86	20,15	20,74	20,27	20,62	20,39	20,51	20,51	64,02	61,83	63,66	62,20	63,30	62,56	62,93	62,93	89
30	21,58	20,84	21,46	20,98	21,34	21,09	21,21	21,21	64,74	62,52	64,38	62,89	64,01	63,27	63,64	63,64	90
31	22,30	21,55	22,17	21,66	22,03	21,79	21,92	21,92	65,46	63,21	65,09	63,59	64,72	63,97	64,35	64,35	91
32	23,02	22,23	22,89	22,36	22,76	22,49	22,63	22,63	66,18	64,01	65,81	64,29	65,43	64,67	65,05	65,05	92
33	23,74	22,92	23,60	23,06	23,47	23,20	23,33	23,33	66,90	64,70	66,52	64,99	66,14	65,37	65,76	65,76	93
34	24,46	23,62	24,32	23,76	24,18	23,90	24,04	24,04	67,62	65,40	67,24	65,68	66,85	66,08	66,47	66,47	94
35	25,17	24,31	25,02	24,46	24,89	24,60	24,75	24,75	68,34	66,09	67,95	66,39	67,56	66,78	67,17	67,17	95
36	25,89	25,01	25,75	25,16	25,60	25,31	25,46	25,46	69,05	66,79	68,67	67,09	68,27	67,48	67,88	67,88	96
37	26,61	25,71	26,46	25,86	26,31	26,01	26,16	26,16	69,77	67,48	69,38	67,89	68,99	68,19	68,59	68,59	97
38	27,33	26,41	27,18	26,56	27,02	26,71	26,87	26,87	70,49	68,18	70,10	68,49	69,70	68,85	69,20	69,20	98
39	28,05	27,10	27,89	27,28	27,73	27,42	27,58	27,58	71,21	68,87	70,81	69,19	70,41	69,59	70,00	70,00	99
40	28,77	27,79	28,61	27,95	28,45	28,12	28,28	28,28	71,93	69,47	71,53	69,88	71,12	70,30	70,71	70,71	100
41	29,49	28,48	29,33	28,65	29,10	28,82	28,99	28,99	72,65	70,16	72,24	70,58	71,83	71,00	71,42	71,42	101
42	30,21	29,18	30,04	29,35	29,87	29,52	29,70	29,70	73,37	70,86	72,96	71,28	72,55	71,70	72,12	72,12	102
43	30,93	29,87	30,76	30,05	30,58	30,23	30,41	30,41	74,09	71,55	73,67	71,98	73,25	72,40	72,81	72,81	103
44	31,65	30,57	31,47	30,75	31,29	30,93	31,11	31,11	74,81	72,25	74,39	72,68	73,96	73,11	73,54	73,54	104
45	32,37	31,26	32,19	31,45	32,00	31,63	31,82	31,82	75,53	72,94	75,10	73,38	74,68	73,81	74,25	74,25	105
46	33,09	31,96	32,90	32,14	32,71	32,34	32,53	32,53	76,25	73,64	75,82	74,08	75,59	74,55	74,95	74,95	106
47	33,81	32,65	33,62	32,84	33,43	33,04	33,23	33,23	76,97	74,33	76,53	74,78	76,10	75,22	75,66	75,66	107
48	34,53	33,35	34,33	33,54	34,14	33,74	33,94	33,94	77,69	75,03	77,25	75,47	76,81	75,92	76,37	76,37	108
49	35,24	34,04	35,05	34,24	34,85	34,44	34,65	34,65	78,40	75,72	77,96	76,17	77,52	76,62	77,07	77,07	109
50	35,97	34,73	35,76	34,94	35,56	35,15	35,35	35,35	79,13	76,41	78,68	76,87	78,23	77,33	77,78	77,78	110
51	36,69	35,43	36,48	35,64	36,27	35,85	36,06	36,06	79,85	77,11	79,40	77,57	78,95	78,04	78,49	78,49	111
52	37,40	36,12	37,19	36,34	36,98	36,55	36,77	36,77	80,56	77,80	80,11	78,27	79,65	78,74	79,20	79,20	112
53	38,12	36,82	37,91	37,04	37,69	37,26	37,47	37,47	81,28	78,50	80,83	78,97	80,37	79,43	79,90	79,90	113
54	38,84	37,51	38,62	37,74	38,40	37,96	38,18	38,18	82,00	79,19	81,54	79,67	81,08	80,15	80,61	80,61	114
55	39,56	38,21	39,34	38,44	39,12	38,66	38,89	38,89	82,72	79,89	82,26	80,37	81,79	80,85	81,32	81,32	115
56	40,28	38,90	40,05	39,14	39,82	39,37	39,59	39,59	83,44	80,58	82,97	81,08	82,50	81,55	82,02	82,02	116
57	41,01																





P1.XII.







THE ELEMENTS OF NAVIGATION.

BOOK VIII. OF GLOBULAR SAILING.

SECTION I.

Definitions and Principles.

1. **B**Y Globular Sailing is meant the manner of estimating either the difference of latitude, difference of longitude, departure, course, or distance, from any two of them being known, upon principles deduced from the spherical figure of the Earth.

In the preceding parts of sailing, the operations were performed as if the courses and distances of ships had been run on a plane or flat surface. But this cannot be true, as appears from Book VI. Art. 2. To which, as farther proofs, it may be added, 1st. That mariners, as they sail from northern or southern latitudes towards the equator, observe the stars about the poles constantly to diminish their altitude or height above the apparent horizon. 2^d. It is also well known, that in eclipses of the moon, the darkened part is bounded by a circular curve; and consequently the body which casts the shade, or obstructs the light, must be bounded by a like curve. But as this obscuration is caused by the Earth, consequently its surface must be limited by a circular figure, that is, it must be globular.

2. As meridians are circles on the terraqueous globe, meeting in the poles, it is obvious that any two of these circles must recede more from one another at greater distances from the poles; and at equal distances from both poles, or at the equator, the distance between the meridians is the greatest.

The true place of a ship at sea depends upon its distance from the equator, and from some noted meridian; and because the meridional distance, that is, the distance between two meridians, varies in every latitude; it is therefore convenient, that this distance should be reckoned in a fixed latitude, and where the degrees are of the same magnitude with those of the meridian; which can be only at the equator, where 60 nautical miles make a degree.

3. Now a ship sailing from any latitude upon an oblique rhumb, until she has made a known departure, by the rules of plane sailing, will reckon herself under the same meridian, whether she sails to the northward or southward. But from what has been said, this cannot be true; for the same meridional distance, which in this case is taken as departure, will not serve two different latitudes on the same side of the equator; therefore the common methods of plane sailing alone are not sufficient to shew the ship's true place, a necessary correction being wanted with respect to her longitude.

The incorrect method of plane sailing was probably founded on the manner in which the sea-charts were at first constructed. For it being most convenient to represent the meridians, parallels of latitude, and rhumb lines in such charts by right lines, where the meridians would be parallel, and the east and west lines cut them at right angles; of consequence the distances of the meridian in every parallel were equal to the distances at the equator; and a degree on any parallel of latitude, was of the same size as a degree on the equator: hence each degree of longitude in those parallels was increased beyond its just size, in proportion as the equator, or its radius, is greater than the parallel, or its radius.

4. These material objections against the sea-charts could be removed only by adopting a different method of constructing them; and it had been hinted, some hundred years since, by several persons, that the degrees of latitude in such charts ought to be lengthened as they approach the poles. Accordingly Mr. *Gerrard Mercator*, a Fleming, published the first chart of this kind in the year 1556, in which the degrees of latitude were gradually lengthened from the equator toward the poles; but in what manner, or how the chart was constructed, he did not shew; neither were those degrees increased in the true proportion.

5. About the year 1590, Mr. *Edward Wright*, an Englishman, discovered the true principles upon which such a chart should be constructed; which is to increase the degrees of latitude as they approach the poles, in the same proportion as the degrees of longitude decrease on the globes. But it was not until the year 1599, when he published his errors in Navigation,

vigation, that he shewed publicly the principles of the true sea-chart, and the method of constructing it: but notwithstanding Mr. Wright was the real inventor, the charts made on this construction are called Mercator charts. However, as a true method of computing a ship's place at sea does not appear to have been known till Mr. Wright published the said book; therefore, although the chart may not improperly be called *Mercator's*, from his being the first publisher of a chart of this kind, yet the method of sailing, called *Mercator's*, should, in justice, be named from Mr. *Wright*.

6. The difficulty of constructing a true sea-chart seems to have consisted in finding a proper manner of applying the surface of a globe to a plane, which Mr. *Wright* happily accomplished by a most ingenious conception; the substance of which follows.

1st. Suppose a rectangular plane were rolled about the globe, until the edges of the plane met, and formed a kind of concave cylinder inclosing the globe, and touching its equator.

2d. Conceive the surface of this globe to swell (like a bladder while it is blowing up) from the equator towards the poles, proportionally in latitude as it does in longitude, until every part of its surface meet that of the concave cylinder, and impress on it the lines that were drawn on the globular surface.

3d. Then the cylinder, or rectangular plane, being unrolled, will represent a sea-chart, the parts of which bear the same proportion to one another, as the corresponding parts on the globe do; and in which all the lines will be right lines.

For in this formation of the nautical chart, every parallel of latitude on the globe will be increased till it is equal to the equator; and so the distance of the meridians in those parallels will become equal to their distance at the equator; consequently the meridians on the chart are expressed by parallel right lines.

Also, the meridians being lengthened as the parallels are increased, every degree of latitude is lengthened in the same proportion as the degrees of longitude are increased; therefore the distances of the parallels of latitude become wider and wider as they approach the poles.

Again. As the rhumb lines on the globe cut the meridians at equal angles, they will also cut the meridians at equal angles on the chart, and consequently be expressed by right lines; since none but right lines can cut several parallel right lines at equal angles.

The construction of such a chart Mr. Wright deduced from the following principles.

SECTION II.

Of the Reckoning of Longitude.

7.

PROPOSITION I.

*The distance between any two meridians at the equator,
Is in proportion to their distance in any parallel of latitude;
As the radius,
To the co-sine of that latitude.*

DEMONSTRATION. See Fig. 1. Pl. XIII.

Let PDEF represent the fourth part of a sphere; E being the center, & the pole, ED the radius of the equator, AB the radius of a parallel of latitude. Then the arcs PBD, PCd, will each represent a quadrant of a meridian; Dd is an arc of the equator, and BC an arc of a parallel of latitude; also the arc DB expresses the latitude, and PB the complement of the latitude, the right sine of which is BA. (III. 3)

Now (II. 197) the circumference of a circle, the radius of which is ED, is to the circumference of a circle, the radius of which is AB, as ED is to AB; that is, as the radius of the equator, to the radius of the parallel; or, as radius to the co-sine of the latitude.

But like arcs, have the same ratio which their circumferences have.

(II. 150, 197)

And like arcs Dd, BC, are intercepted between the same two meridians; therefore

An arc of the equator is to a like arc in any parallel of latitude,
As the radius, to the co-sine of that latitude.

8. COROL. Hence it is easy to construct a table shewing the approach of two meridians in any latitude from the equator to the poles; or in what proportion the degrees of longitude diminish in every latitude.

9.

PROPOSITION II.

Any part of a parallel of latitude is to a like part of a meridian, as radius is to the secant of the latitude of that parallel.

DEMONSTRATION. See Fig. 2. Pl. XIII.

Let PDE represent a quadrant of a meridian, where P is the pole, and DE the radius of the equator; AB is the radius of a parallel of latitude, or is the co-sine of the latitude, the sine of which is BF, and secant EC.

Then EF : EB :: ED : EC.

(III. 34)

Or cos. lat. : rad. :: rad. : secant of the lat. in that parallel.

But cos. lat. : rad. :: part of a parallel : like part of the equator. (7)

Therefore, part of a parallel of latitude, is to a like part of the equator;
As the radius is to the secant of the lat. to that parallel.

Now like parts of the meridian and equator are equal, as great circles.

Therefore any part of a parallel of lat. is to a like part of a meridian;
as radius, to the secant of the lat. to that parallel.

10. PRO-

10.

PROPOSITION III.

The distance of any parallel of latitude (A) from the equator is expressed by the sum of the secants of all the arcs between the equator and that parallel.

DEMONSTRATION.

Now (9) As radius, to the secant of the latitude A ;
So is a diminished deg. of long. in lat. A, or a degree of that parallel, to a degree of the meridian.

But the degrees of latitude, or of the meridian, are to be lengthened in proportion as the degrees of longitude diminish. (5)

Therefore, As radius, to the secant of the latitude A ;

So is a natural deg. of the meridian, to a lengthened deg. in lat. A.

Here radius being as unity, and one natural deg. as unity also,

The length of a degree in any latitude is as the secant of that latitude, or may be expressed by that secant.

Now the distance of any parallel from the equator is the sum of all the successive arcs between the equator and that parallel.

Consequently the distance of that parallel is expressed by the sum of the secants of all these arcs between the equator and that parallel of latitude.

II. COR. Hence it appears that by the addition of the secants of small arcs the distances of the parallels of latitude from the equator are obtained.

And these several distances, which are called *meridional parts*, being disposed in a table corresponding to the degrees and minutes in a quadrant, form a table of meridional parts.

This was the excellent discovery of the celebrated Mr. *Wright*, by which the art of Navigation received greater improvements than by any thing that had been done before, the discovery of the mariner's compass excepted ; and indeed, in this and other things, he so far perfected the art, that little else was wanted beside an accurate method to find the longitude at sea. There have been since his time many eminent men, who have done much towards rendering Navigation more perfect ; yet if the real use of their improvements be strictly considered, it will perhaps be found, that they amount to no more than other methods of performing the same operations : the improvements made by Mr. *Richard Norwood* and Dr. *Halley* only excepted.

12. Mr. *Wright* made his table for the division of the nautical meridian, or the table of meridional parts, as follows.

The meridional parts for 1 min. he made equal to the secant of 1 min.

The mer. parts to 2 min. equal to the sum of the sec. of 1 and 2 min.

The mer. parts to 3 min. equal to the sum of the sec. of 1, 2, and 3 m.

The mer. parts to 4 m. equal to the sum of the mer. parts of 3 min. and the sec. of 4 min.

And so on by a constant addition of the secants.

Now although a table thus made is abundantly sufficient for all nautical uses; yet, had the secants of smaller parts than minutes been taken, the table would have been more correct. And therefore Mr. Oughtred, Sir Jonas Moore, Dr. Wallis, Dr. Halley, and others, have been induced to seek methods of constructing these tables with more accuracy than by the addition of the secants to every minute.

But a table of meridional parts constructed by the most accurate method, has only shewed, that Mr. Wright's table does no where exceed the true meridian parts by half a minute, and this only near the pole; for in latitudes, as far as navigation is practicable, the difference is scarce sensible.

A table of meridional parts being obtained (see the table at the end of this book) the meridians and parallels of latitude for a sea chart, in which the situation of places will bear the same proportion to one another as on the globe, may be constructed by the following proposition.

13.

PROPOSITION IV.

To construct a sea-chart, which shall contain a given number of degrees of latitude and longitude.

Suppose from the latitude of 23 degrees N. to the lat. of 59 degrees N. with 80 degrees of west longitude from the meridian of London.

SOLUTION.

1st, Write the several degrees of latitude, included between the proposed limits, orderly under one another in a column, the greatest being uppermost.

2d. Then beginning at the lower one, write in another column, against each degree, the difference * between the meridional parts of the lesser latitude, and of that degree of latitude.

3d. Divide each of these meridional differences by 60, setting the quotients against their respective dividends, in another column; and these will be the meridional parts reduced to degrees of longitude, and will express the measures of the divisions for the meridional degrees.

If the meridional differences to parts of degrees, or minutes, be wanted, they are to be taken from the table of meridional parts in the same manner.

These three articles are exemplified in the following table; which, although made to serve from the equator to 72 degrees of latitude, yet will serve for any intermediate limits, by subtracting the meridional degrees belonging to the latitude where the chart is to begin from those of all the latitudes the chart is to contain: from the several remainders make a table, and these will be the numbers to be transferred to the chart, as is shewn in what follows.

* This is best done by writing the merid. parts of the lesser lat. close to the upper edge of a bit of paper, of the same size with the tabular figures; then this number being applied to the mer. parts of the other degrees, the differences may be readily taken.

A TABLE for constructing a Mercator's Chart.

Lat.	Mer. Parts	Mer. Deg.	Lat.	Mer. Parts	Mer. Deg.	Lat.	Mer. Parts	Mer. Deg.	Lat.	Mer. Parts	Mer. Deg.
72	6335	105,6	54	3865	64,4	36	2318	38,6	18	1098	18,3
71	6146	102,4	53	3764	62,7	35	2244	37,4	17	1035	17,2
70	5966	99,4	52	3665	61,1	34	2171	36,2	16	0973	16,2
69	5795	96,6	51	3569	59,5	33	2100	35,0	15	0910	15,2
68	5631	93,8	50	3475	57,9	32	2028	33,8	14	0848	14,1
67	5474	91,2	49	3382	56,4	31	1958	32,6	13	0787	13,1
66	5324	88,7	48	3292	54,9	30	1888	31,5	12	0725	12,1
65	5179	86,3	47	3203	53,4	29	1819	30,3	11	0664	11,1
64	5039	84,0	46	3116	51,9	28	1751	29,2	10	0603	10,1
63	4905	81,7	45	3030	50,5	27	1684	28,1	9	0542	9,0
62	4775	79,6	44	2946	49,1	26	1616	26,9	8	0482	8,0
61	4649	77,5	43	2863	47,7	25	1550	25,8	7	0421	7,0
60	4527	75,5	42	2782	46,4	24	1484	24,7	6	0361	6,0
59	4409	73,5	41	2702	45,0	23	1419	23,6	5	0300	5,0
58	4294	71,6	40	2623	43,7	22	1354	22,6	4	0240	4,0
57	4183	69,7	39	2545	42,4	21	1289	21,5	3	0180	3,0
56	4074	67,9	38	2468	41,1	20	1225	20,4	2	0120	2,0
55	3968	66,1	37	2393	39,9	19	1161	19,3	1	0060	1,0

4th. Draw a line AB (see Plate XII.) to represent a part of the parallel of latitude where the chart is to begin (which in this example is the parallel of 23°); and on this line, by the help of a scale of equal parts, lay a number of successive divisions to express the proposed number of degrees of longitude.

Thus 80 degrees of longitude being proposed, from some scale take one of the primary divisions, and this distance being repeated eight successive times in the line AB, will give divisions to every tenth degree of longitude, and then let the intermediate degrees be inserted, and AB will be divided into 80 equal parts of that scale; which, in this example, is the scale where eight subdivisions or degrees make an inch: in like manner the parts of degrees may be inserted.

5th. From the ends A, B, draw lines AD, BC, perpendicular to AB; and on these lines lay the divisions expressed by the meridional degrees in the foregoing table, beginning at the line AB.

Thus, if the chart began at the equator, and extended to 70 degrees of latitude; for 70 deg. take 99,4; for 69 deg. take 96,6; for 68 deg. take 93,8, &c.; and these divisions taken from the same scale, and laid severally on AD, BC, will give the divisions for the degrees of latitude increased in their true proportion; and the like for the intermediate parts of degrees.

Rut

But the chart beginning at 23 deg. of lat. its meridional degrees 23,6 are to be subtracted from those belonging to all the latitudes to be introduced in the chart. The respective remainders are shewn in the following table :

Deg. Lat.	Mer. Deg.	Deg. Lat.	Mer. Deg.	Deg. Lat.	Mer. Deg.	Deg. Lat.	Mer. Deg.	Deg. Lat.	Mer. Deg.	Deg. Lat.	Mer. Deg.
59	49,9	53	39,1	47	29,8	41	21,4	35	13,8	29	6,7
58	48,0	52	37,5	46	28,3	40	20,1	34	12,6	28	5,6
57	46,1	51	35,9	45	26,9	39	18,8	33	11,4	27	4,5
56	44,3	50	34,3	44	25,5	38	17,5	32	10,2	26	3,3
55	42,5	49	32,8	43	24,1	37	16,3	31	9,0	25	2,2
54	40,8	48	31,2	42	22,8	36	15,0	30	7,0	24	1,1

Then these meridional degrees, taken from the same scale used for the degrees of longitude, are to be applied to the meridians BC, AD; so that the meridian extent of the chart will be 49,9 such divisions, as the parallel extent eastward contains 80.

6th. Draw lines through the several corresponding divisions of latitude, and they will represent the parallels of latitude; lines drawn through the divisions of longitude, will express the meridians or parallels of longitude. In this example, the meridians and parallels are drawn only to every 10 degrees.

7th. From some point of the chart, as a center, let the rhumb lines be drawn.

14. Note, The difference between the meridional parts to two given latitudes is called the MERIDIONAL DIFFERENCE OF LATITUDE, to distinguish it from the difference of latitude of those two places reckoned in miles of the equator, which is called the *proper difference of latitude*.

In a chart thus constructed, every place may be laid down in its true position, with regard to other places, by its latitude and longitude, with as much accuracy as on the globe itself, the distances of the meridians and parallels of latitude having the same proportion to one another in both. Thus, on the globe, the distance of two meridians in the parallel of 60 degrees is half their distance at the equator, because the co-sine of 60 degrees is half the radius (III. 24); so in the chart, at the latitude of 60 degrees, the meridional difference of latitude to one minute is double to the meridional difference of latitude of one minute from the equator, the secant of 60 degrees being double to the radius (III. 24, 34); and the like analogy holds in other corresponding latitudes.

Now as the meridians are parallel right lines, and are cut at right angles by the parallels of latitude, and the rhumbs also being right lines; such a chart is of more service to the mariner for most purposes, than the globe is.

The properties of the several lines and angles used in sailing by this chart will be shewn in the following propositions.

PROPOSITION V.

15.

If a ship sails on any oblique rhumb, the proper difference of latitude to the departure, the meridional difference of latitude to the difference of longitude, and the radius to the tangent of the course, are all in the same ratio. See Fig. 1. Pl. XII.

DEMONSTRATION.

Suppose a ship from P in the latitude of 30 deg. N. sails on the rhumb ps, to s in the latitude of 40 degrees north.

Now because she has made 10 deg. of diff. lat. ; make PO, in the meridian, equal to 10 degrees of the equator ; and draw o R parallel to Qs, meeting the rhumb P s in R.

Then PO expresses the proper difference of latitude.

OR the departure.

PR the distance sailed in equatorial measure.

$\angle OPR$ is the angle of the course.

And R is the apparent place of the ship.

But having made 10 deg. diff. lat. she should be in the parallel of 40 degrees ; her place therefore, when corrected by longitude, will be in s.

Then QS will be the difference of longitude.

And PQ the meridional difference of latitude.

Now the triangles POR, PQS, are similar.

Therefore $PO : OR :: PQ : QS.$

(II. 167)

Also $PO : OR :: \text{rad.} : t. \angle OPR.$

(III. 46)

Consequently. As the proper diff. lat., to the departure ;

So the merid. diff. lat., to the diff. longitude.

And So is the radius , to the tang. of the course.

16.

PROPOSITION VI.

The tangents of the angles which different rhumbs make with the meridians, are directly proportional to the differences of longitude made on those rhumbs to equal meridional differences of latitude : Or, are reciprocally proportional to unequal meridional differences of latitude on those rhumbs, when the differences of longitude are equal. See Fig. 1. Plate XII.

DEMONSTRATION.

Let QS, QV, be the differences of longitude made on the rhumbs ps, pv, to the common merid. diff. lat. PQ ; also PW, PQ, be the meridional differences of latitude, on the same rhumbs, to the equal differences of longitude wx, QV.

Now $PQ : QV :: R : t. \angle QPV$

And $PQ : QS :: R : t. \angle QPS.$

} (III. 46)

Consequently $QV : QS :: t. \angle QPV : t. \angle QPS.$

(II. 155)

Again. Since $R : t. \angle QPV :: PQ : QV$

And $R : t. \angle WPX :: PW : QV (=wx)$

} (III. 46)

Then $R \times QV = PQ \times t. \angle QPV = PW \times t. \angle WPX$

(II. 162)

Consequently $PW : PQ :: t. \angle QPV : t. \angle WPX.$

(II. 46, 163)

17. PROP.

17.

PROPOSITION VII.

If a ship sails on several different rhumbs, the whole meridional diff. lat. is equal to the sum, or difference of all the successive meridional differences of lat. : And the whole diff. long. is also equal to the sum, or differences of all the successive differences of longitude; the sums being taken when they are of the same name; and the differences when of contrary names. See Fig. 2. Plate XII.

DEMONSTRATION.

1st. Suppose a ship sails from E in the lat. of 23° N. to G in the parallel of 26 deg. N. Then $Eg = \text{mer. diff. lat.}$ and $Gg = \text{diff. long.}$

2d. To sail from G to H in the parallel of 28 deg. Then $Gh = \text{diff. lat.}$ and $hH = \text{diff. long.}$

Now $E m = Eg + Gh$, is the whole diff. latitude.

And $mH = mb - Hh$, is the whole diff. longitude.

3d. She sails west from H to I: here she only alters her longitude by HI ; so that her present diff. long. is mI .

4th. In sailing from I to K, she increases her diff. long. by kK , from mI to gK ; and decreases her diff. lat. by Ik , from $E m$ to Eg .

5th. In sailing north from K to P, the diff. long. pP continues the same; but the diff. lat. is increased by KP , from Eg to Ep .

6th. In running east from P to M, the diff. lat. Ep does not alter; but the diff. longitude is diminished from pP to pM .

7th. By going from M to N, the diff. lat. is increased by Ml , from Ep to Eq ; and the diff. long. is changed from pM , or ql , to qN .

Consequently the whole diff. lat. Eq is equal to the sums, or differences of all the differences of lat.; and the same of qN , the whole difference of longitude.

18.

PROPOSITION VIII.

If the course between any two places, outward and homeward, be on the opposite rhumbs; then in each case the differences of latitude, departures, and differences of longitude, will always be the same. See Fig. 3. Plate XII.

DEMONSTRATION.

Suppose a ship at a in lat. 25 deg. N. sails on one rhumb to the latitude 40 deg. N. so that at the end of every third day she alters her diff. lat. five deg. or 300 miles; and returns, on the opposite rhumb, in the same manner.

Through the intersections a of this rhumb, with the parallel of every five degrees, draw meridians; make ad , af , each equal to five common degrees of the equator; and draw db , fe , parallel to the parallels of latitude.

Then are the lines ad the proper differences of latitudes outward to each third day's account, which must be every where equal; and also, the equal lines af are the differences of latitude homeward to the like accounts.

The

The lines db outward, and fe homeward, are the departures to each third day's account.

The lines ab outward, and ae homeward, are the distances run to each third day's account.

The meridian lines ac outward, and an homeward, are the meridional differences of latitude; and the west and east lines ca outward, and na homeward, taken on the parallels of latitude, are the differences of longitude.

Now it is evident from the construction that the triangles adb , afe , in each account, are equal to one another.

Also, that the meridional differences of latitude, and the differences of longitude, to the accounts between the same parallels of latitude outward and homeward, are respectively equal to one another.

Consequently the truth of the proposition is manifest.

19.

PROPOSITION IX.

The divisions of the meridian line on the Mercator's chart form a table of the differences of longitude answering to each minute of latitude on the rhumb line making an angle of 45 degrees with the meridian. See Fig. 1. Pl. XII.

DEMONSTRATION.

Let PV be a rhumb of 45 degrees.

Then, since PQ is at right angles to QV .

The angle $QPV = \angle QVP$, each being half a right angle.

Consequently $QV = QP$.

(II. 104)

Now PQ is the sum of all the meridional differences of latitude between the parallels through P and Q .

(II)

And QV is the sum of all the differences of longitude between the meridians through Q and V .

Therefore on a rhumb of 45 degrees, the sum of all the differences of longitude is equal to the sum of all the meridional differences of latitude.

But the sum of all the meridional differences of latitude is the same as the nautical meridian.

(12)

Consequently, on a rhumb of 45 degrees the difference of longitude, or the sum of all the intermediate differences of longitude to every minute of latitude, is equal to the corresponding parts of the nautical meridian line.

20. In the Philosophical Transactions, N^o 219, Dr. Halley has given a very curious paper relating to the division of the nautical meridian, by a method quite different from Mr. Wright's; and because it contains a method of performing the problems of sailing according to the true chart, by the help of Briggs's, or the common table of logarithmic tangents, without a table of meridional parts; the substance of that paper is here annexed.

The Doctor says: "It was first discovered by chance, and, as far as I can learn, first published by Mr. *Henry Bond*, as an addition to *Norwood's Epitomy of Navigation*, about the year 1645, that *the meridian line was analogous to a scale of logarithmic tangents of half the complements of the latitude*. The difficulty to prove the truth of this proposition seemed such to Mr. *Mercator*" (an ingenious mathematician then living, and) "the author of the *Logarithmotechnia*, that he proposed to wager a good sum of money, against who so would fairly undertake it, that he should not demonstrate either that it was true or false: And about that time Mr. *John Collins* holding a correspondence with most of the eminent mathematicians of the age, did excite them to this enquiry.

"The first that demonstrated the said analogy was the excellent Mr. *James Gregory*, in his *Exercitationes Geometricæ*, published anno 1668, which he did, not without a long train of consequences and complication of proportions, whereby the evidence of the demonstration is in a great measure lost, and the reader wearied before he attains it." The Doctor proceeds, "Nor hath any one, that I know of, yet discovered the rule for computing independently the interval of the meridional parts answering to any two given latitudes."

The Doctor then gives the demonstration of the said analogy in a very elegant manner; and draws several useful conclusions. But, as he confesses himself, he is too concise for learners; and the writers on this subject have been no less so. In order therefore to set this affair in a clear light, and to keep to the Doctor's principles, it was thought convenient to dispose of the subject in the following manner; but the proposition may be proved from principles very different from those which were used by the Doctor.

21.

PROPOSITION X.

On the globe, the rhumb lines oblique to the meridians are spirals, which continually approach the poles.

DEMONSTRATION.

In any place on the surface of the globe the rhumb running north and south, coincides with the meridian of that place; the east and west rhumbs are perpendicular to the meridian, and the other rhumbs are oblique to it; but this obliquity is the same under every meridian; therefore all the rhumbs, except the north and south, cut the meridians at equal angles.

When right lines are parallel to each other, a right line will cut them at equal angles (II. 95): But not so, when the lines are inclined to one another; therefore several inclining lines cannot be cut at equal angles, except by a curve line bending toward the place where those lines would meet.

Now the meridians on the globe, meeting in the poles, are inclined to one another; therefore the oblique rhumbs cutting them at equal angles, are curve lines continually approaching the poles.

22. PRO-

22. PROPOSITION XI.

The spiral rhumbs on the globe become proportional spirals in the stereographic projection on the plane of the equator. See Fig. 3. Plate XIII.

DEMONSTRATION.

Let CAEB represent part of a stereographic projection of the sphere on the plane of the equator, where AEB is part of the equator, c the pole, CA, CD, CE, &c. are meridians, and the spiral A d e f one of the rhumbs.

Now in every stereographic projection the lines intersecting each other form angles equal to the angles on the sphere which they represent.

(IV. 52)

Therefore the projection of the rhumb line A d e f cuts the radii or meridians AD, AE, &c. at equal angles.

But this is a property also of the proportional spiral. (II. 225)

Therefore the spiral rhumbs on the globe become proportional spirals in this projection.

23. COR. Hence the differences of longitude AD, AE, AF, &c. are logarithms of the ratios of the intercepted parts c d, c e, c f, &c. of the meridians to the radius CA.

24. PROPOSITION XII.

The meridian line is a scale of logarithmic tangents of half the complement of the latitudes beginning from the radius.

DEMONSTRATION.

Let the figure CADEB be part of the stereographic projection of the sphere on the plane of the equator, as in the last proposition: and on any rhumb let the points A, d, e, f, &c. represent certain places on the globe, of which A is a point in the equator; then will D d, E e, F f, &c. express their respective latitudes, and the arcs AD, AE, AF, &c. their differences of longitude from the longitude of A; also c being the pole, the lines c d, c e, c f, &c. are the projections of the complements of their latitudes.

Now in this projection the lines c d, c e, c f, &c. are equal to the tangents of half the complements of those latitudes. (IV. 48)

And the differences of longitude AD, AE, AF, &c. are logarithms of the ratio of those tangents, or of the lines c d, c e, c f, &c. to the radius CA.

Also the lengthened degrees of the nautical meridian line are the longitudes of those degrees made on the rhumb of 45 degrees, whether expressed in minutes, according to the usual tables, or in degrees, as some writers have done.

25.

PROPOSITION XIII.

The logarithmic tangent of half the complement of any latitude in Napier's original system, divided by 0,0002908882, &c. first multiplied by the radius of the tables, exhibits in minutes the change in longitude, which will be made on the rhumb of 45 degrees from the equator to that latitude; or the lengthened degrees in the meridian line from the equator to that latitude.

DEMONSTRATION.

The differences of longitude AD, AE, AF, &c. being on the rhumb of 45°, logarithms to c d, c e, c f, &c. which begin from the radius, and proceed from thence, in like manner as Napier's logarithmic tangents do from his radius :

Therefore his logarithmic tangent of half the complement of any latitude bears to his radius the ratio of the arc of longitude accompanying the change of latitude to the radius of that arc, consequently it is the ratio of the number of minutes contained in that arc to the measure of the radius in minutes. (II. 229)

Hence the logarithm will also be to the radius of the table multiplied by 0,0002908882, &c. (the arc of one minute, when the radius is unity) as the number of minutes in this arc is to the measure of the radius in minutes multiplied by 0,0002908882, &c. that is, to one minute; for the measure of the radius in minutes is to one minute, as unity to 0,0002908882, &c.

Therefore the number of minutes contained in the longitude, or the lengthened degrees in the meridian line, is equal to the logarithm named, divided by 0,0002908882, &c. first multiplied by the radius of the table.

26. COR. Napier's radius being 10000000, the logarithmic tangent will be divided by 2908,882, &c.

If the difference between the logarithmic tangents of half the complements of any two latitudes, when on the same side of the equator, or their sum, if one latitude be north and the other south, be divided in the same manner, the quotient shall give the meridional parts for the interval between the two latitudes.

27.

PROPOSITION XIV.

If in Briggs's logarithms the index, or characteristic alone be considered as an integer, and all the rest as an appendage of decimals, the difference between the logarithm of the radius, and the logarithmic tangent of half the complement of the latitude of any place divided by 0,00012633114, &c. gives the minutes of the change of longitude in passing on the rhumb of 45° to the latitude of that place, or the meridional parts corresponding to that latitude.

DEMONSTRATION.

Briggs's logarithms thus interpreted are to Napier's original logarithms, as 1 to Napier's logarithm of 10 (or rather to his logarithm of the ratio between 10 and 1) which is nearly 23025851 *, and the difference

* The number usually set down, as Napier's logarithm of 10, is more properly his logarithm divided by the radius of his trigonometrical table, which is the radix from which he raised his logarithms.

named are logarithms of the respective tangents to the radius. Therefore these divided by $\frac{2908,882}{23025851}$ ($=0,00012633114$, &c.) will produce the same quotient, as Napier's logarithms assigned to the same tangents (which are the logarithms of the ratio of those tangents to the radius in his system) divided by 2908,882: this quotient therefore will be the minutes of the change of longitude on a rhumb of 45° , that is, the length of the meridian line.

28. COR. If the difference from the radius of the logarithmic tangent, taken from any table of logarithms of Briggs's form, be considered as consisting wholly of integers, and divided by 12633114, &c. in which so many figures shall be esteemed integers, as are four short in number of the logarithmic tangent taken, the index included, the quotient shall give the meridional parts appertaining to that latitude *.

Also here, if in any logarithmic table of the common form, the difference between the logarithmic tangents of half the complements of any two latitudes on the same side of the equator, or their sum if one latitude be north and the other south, be considered, as an integer number, and divided in like manner, the quotient shall be the meridional parts for the interval between the two latitudes.

SCHOLIUM.

29. The numbers in Napier's table divided by 2908,882, &c. exhibiting the change of longitude on a rhumb of 45° , the tangent of which is equal to the radius, the numbers themselves will express the change in longitude on a rhumb, the tangent of which is 2908,882, &c. times the radius, and the angle $89^\circ 58' 49''$; and if the logarithm be divided by 10, 100, or 1000, the angle of the rhumb will respectively be $89^\circ 48' 11''$, $88^\circ 1' 52''$, or $71^\circ 1' 42''$, which is the angle Dr. Halley has chosen.

After the same manner in Briggs's system, the difference of the tangent of half the complement of any latitude from the radius divided by 0,00012633114, &c. exhibiting the corresponding length of the meridian line, should the index of the logarithm be alone considered as an integer number, those differences will be the change of longitude on a rhumb, the tangent of which is equal to the radius of any trigonometrical canon of Briggs's form multiplied by 0,0001263311438, &c. and the angle $0^\circ 0' 26''$. But if one figure besides the index be taken as integer, the tangent of the rhumb will be the radius multiplied by 0,0012633, &c. the angle being $0^\circ 4' 20\frac{1}{2}''$; if two, the angle will be $43' 25\frac{1}{2}''$; if three, the angle will be $7^\circ 12' 0''$; and if four, as Dr. Halley proposes, the angle will be $51^\circ 38' 9''$.

From the preceding propositions all the problems relating to the true method of sailing may be accurately resolved; and although they are here all contained under the general title of globular sailing, yet as the

* Thus when the tables of logarithms have eight places with the index, the divisor will be 1263,3, &c. but when the tables consist of 7 or 6 places, the divisor will be 126,33, &c. or 12,633, &c.; and so on.

common custom has been to distinguish different kinds, in which the longitude is considered; so here, in compliance with such custom, it was thought proper to retain the usual forms, viz. *parallel sailing*, *middle latitude sailing*, and *Mercator's sailing*, or more properly *Wright's sailing*; which are distinctly treated of in the following sections.

SECTION III.

Of Parallel Sailing.

30. PARALLEL SAILING is the art of finding what distance a ship should run due east or west, in sailing from the meridian of one place to that of another place, in any parallel of latitude.

This kind of piloting is generally used in conducting a ship to an island, which lies at a considerable distance from the main land, or other islands; and also on some other occasions.

The method of performing which is to sail to the parallel of latitude the place is in, keeping a good account, so as to be certain whether the place is then to the eastward, or westward; and also, if possible, to know the longitude arrived at; and then to run due west, or east, until the ship comes near the longitude of the given place, where she is sure to make the port required.

The computations in parallel sailing depend on the following

RULE.

- | | |
|---|------|
| 31. As radius, | = R. |
| To the co-sine of the latitude of any parallel; | = S. |
| So is the miles of longitude between any two meridians, | = L. |
| To the distance of those meridians in that parallel. | = D. |

For the demonstration, see Art. 7.

From the same proposition is easily deduced the following

RULE.

- | | |
|--|------|
| 32. As the co-sine of one latitude, | = S. |
| Is to the co-sine of another latitude; | = s. |
| So is a given meridional distance in the first parallel, | = D. |
| To the corresponding meridional distance in the second parallel. | = d. |
33. And hence arise the following proportions.

$$\begin{array}{lcl}
 R : S :: L : D. \\
 S : R :: D : L. \\
 L : D :: R : s. \\
 S : s :: D : d. \\
 D : d :: S : s.
 \end{array}$$

By which all the cases that can happen in this kind of sailing are readily resolved by the logarithms, and also by the following table, calculated for a difference of longitude of 1 degree, or 60 nautical miles of the equator, by the first rule. Thus,

As radius, to the co-sine of any latitude; suppose 30° ;

So 60 miles of longitude, to the meridional distance 51,96.

And the like to the other latitudes.

34. A TABLE shewing how many miles answer to a degree of longitude, at every degree of latitude.

Lat.	Miles	Lat.	Miles	Lat.	Miles	Lat.	Miles	Lat.	Miles	Lat.	Miles
1	59,99	16	57,67	31	51,43	46	41,68	61	29,09	76	14,51
2	59,96	17	57,38	32	50,88	47	40,92	62	28,17	77	13,50
3	59,92	18	57,06	33	50,32	48	40,15	63	27,24	78	12,48
4	59,85	19	56,73	34	49,74	49	39,36	64	26,30	79	11,45
5	59,77	20	56,38	35	49,15	50	38,57	65	25,36	80	10,42
6	59,67	21	56,01	36	48,54	51	37,76	66	24,41	81	9,38
7	59,56	22	55,63	37	47,92	52	36,94	67	23,44	82	8,35
8	59,42	23	55,23	38	47,28	53	36,11	68	22,48	83	7,32
9	59,26	24	54,81	39	46,63	54	35,27	69	21,50	84	6,28
10	59,09	25	54,38	40	45,96	55	34,41	70	20,52	85	5,23
11	58,89	26	53,93	41	45,28	56	33,55	71	19,53	86	4,18
12	58,69	27	53,46	42	44,59	57	32,68	72	18,54	87	3,14
13	58,46	28	52,97	43	43,88	58	31,79	73	17,54	88	2,09
14	58,22	29	52,47	44	43,16	59	30,90	74	16,54	89	1,05
15	57,95	30	51,96	45	42,43	60	30,00	75	15,53	90	0,00

The use of this table will be evident from what follows :

35. If the meridional distance is wanted to degrees and minutes, proceed thus :

Take the difference of the meridional distances to the given degrees, and those which are next greater ; multiply this difference by the given minutes, and divide the product by 60 ; then the quotient subtracted from the miles against the given degrees in the table, will leave the meridional distance required.

36. But if a meridional distance, intermediate to those in the table, was given to find the corresponding degrees and minutes.

Subtract the given meridional distance from the next greater, found in the table ; multiply the remainder by 60 ; divide the product by the difference of the meridional distances next greater and less than the given one ; then the quotient being annexed as minutes to the degrees of the next greater meridional distance, will give the degrees and minutes sought.

EXAM. to the first Rule.

How many miles answer to a degree of long. in the lat. of $48^{\circ} 26'$?

Lat. 48° 40,15 miles.

Lat. 49 39,36 miles.

The diff. is 0,79, which multiplied by 26 gives 20,55 ; this divided by 60 gives 0,38 ; which taken from 40,15 leaves 39,77, the miles required.

EXAM. to the second Rule.

In what. lat. do 46,08 miles answer to one deg. of longitude ?

From 46,63, the miles to 39° .

Take 46,08, the given miles.

Leaves 0,55 ; which multip. by 60 gives 33,00 ; this divided by 0,67, the diff. between 39° and 40° , gives $49'$. So $39^{\circ} 49'$ is the lat. sought.

O 2

37. CASE

37. CASE I. Given the latitude and difference of longitude; required the distance.

EXAM. A ship in the latitude of 32° N. sails due east till her difference of longitude is 384 miles: Required the distance she has run.

By CONSTRUCTION*. Fig. 4. Pl. XIII.

From any point P, with the radius of 90° , taken from the scale of natural sines, describe the arc EQ; draw the chord EQ equal to 384 miles taken from a scale of equal parts; and draw the radii PE, PQ.

From the same point P, with a radius equal to the sine of 58° (the comp. lat.) taken from the nat. sines describe the arc AB; and draw the chord AB, the measure of which is the distance sought.

Here P represents the north pole; the arc EQ the equator; the arc AB a parallel of latitude; the chord EQ is the difference of longitude; the chord AB is the meridional distance sought; A is the place sailed from, B the place arrived at; and the radii PE, PQ, express the meridians of the places so sailed from, and arrived at.*

By COMPUTATION.

As radius	=	$90^{\circ} 00'$	10,00000
To co-f. lat.	=	$32^{\circ} 00'$	9,92842
So miles long.	=	384	2,58433
To miles dist.	=	325,6	<u>2,51275</u>

So that she has run 325,6 miles.

By the TABLE.

(34)

Seek the miles to the given latitude; multiply them by the given diff. longitude; the quotient divided by 60 will give the meridional distance sought.

Thus. To lat. 32° answers 50,88 miles.

Multiply 384 the given diff. longitude.

$$\begin{array}{r} 20352 \\ 40704 \\ 15264 \\ \hline \end{array}$$

60)19537,92 (325,632 = merid. dist. sought.

* This and the construction of the following cases depend on the Orthographic projection† of the circles of the sphere on the plane of the equator, that circle being the primitive, and its center or pole representing the point into which the pole of the Earth is projected; consequently the distance from the pole of any parallel of latitude, must be expressed by the complement of that latitude.

† This projection is formed by supposing that any point on the surface of a sphere is projected on a plane passing through its center, by a line drawn through that point perpendicular to the plane; which amounts to the same, as if the visual ray came from an eye at an infinite distance.

Thus in Fig. 1. Pl. XIII. perpend. lines through a, b, project those points in t, z, on the plane r d n e: Therefore small circles on that plane are described with the radii at, ez = the sines of the arcs P a, P b.

38. CASE

38. CASE II. Given the latitude and meridional distance; required the difference of longitude.

EXAM. *A ship from the latitude $53^{\circ} 36'$ N. longitude $10^{\circ} 18'$ E. sails due west 236 miles: Required her present longitude.*

By CONSTRUCTION. Fig. 4. Pl. XIII.

From the point P, with the sine of 90° , and the co-sine of $53^{\circ} 36'$, describe the arcs EQ, CD. Draw the chord $CD=236$; through c and D draw the radii PE, PQ; then the chord EQ being drawn, will be the difference of longitude.

By COMPUTATION.				6,039,8(6° 38'.	
As PC, the co-s. lat.	=	$53^{\circ} 36'$	0,22664	Long. from	10 18E.
To PE, radius	=	90 00	10,00000	Diff. long.	6 38W.
So CD, merid. dist.	=	236 m.	2,37291		
To EQ, diff. long.	=	397.7	2,59955	Long. in	3 40E.

By the TABLE.

Find the meridional distance to a deg. of long. in lat. $53^{\circ} 36'$ (35), and make it a divisor to the product of the given meridional distance by 60; then will the quotient be the diff. long. sought.

Thus. The diff. merid. dist. to 53° and 54° , is 0,85; which multiplied by $36'$, and divided by $60'$, gives 0,51; this taken from 36,11, the merid. dist. to 53° , leaves 35,6 for the merid. dist. to $53^{\circ} 36'$: Then 236 multiplied by 60, and the quotient divided by 35,6, gives 397,7 for the diff. long. sought.

39. CASE III. Given the difference of longitude, and its corresponding meridional distance; required the parallel of latitude.

EXAM. *In what latitude do 384 miles of meridional distance answer to 500 miles of diff. longitude?*

By CONSTRUCTION. Fig. 5. Pl. XIII.

From the point P, with the sign of 90° , describe the arc EQ; draw the chord $EQ=500$, and draw the radii PE, PQ; make $EC=384$, draw CB parallel to EP; then the arc AB being described with the radius PB, is the parallel of lat. sought.

By COMPUTATION.					
As EQ, the diff. long.	=	500	7,30103	So in the lat. $39^{\circ} 49'$ 384 miles of merid. dist. answer to 500 miles of longitude.	
To AB, merid. dist.	=	384	2,58433		
So PE, radius	=	$90^{\circ} 00'$	10,00000		
To PA, the co-s. lat.	=	39 49	9,88536		

By the TABLE.

The given merid. dist. 384 being multiplied by 60, and the product divided by the given diff. long. 500, gives 46,08, the merid. dist. to one deg. of long. in the lat. sought: and by article 36, the latitude will be found to be $39^{\circ} 49'$.

40. CASE IV. Given the distance of two places in a given parallel of latitude; required the distance of two other places, under the same meridians with the former, in another given parallel of latitude.

EXAM. *From two ports in the lat. $32^{\circ} 20'$ N. distant 256 miles, two ships sail directly north: How far are they distant from one another, when they come to the lat. $44^{\circ} 30'$ N.?*

By CONSTRUCTION. Fig. 6, Pl. XIII.

From the point P, with radii equal to the co-sines of $32^{\circ} 20'$, and $44^{\circ} 30'$, describe the arcs AB, DE; draw the chord AB=256, and draw PA, PB; then will the chord DE be the dist. sought.

By COMPUTATION.

As PA, the co-f. of lat. from	= $22^{\circ} 20'$	0,07317
To PD, the co-f. of lat. in	= $44^{\circ} 30'$	9,85324
So AB, the first dist.	= 256	<u>2,40824</u>
To DE, the present dist.	= 216,1	<u>2,33465</u>

By the TABLE.

The merid. distances to $32^{\circ} 20'$, and $44^{\circ} 30'$ (found by 35) are 50,7 and 42,8: then the given merid. distance 256 multiplied by 42,8, and the product 1095,68 divided by 50,7, the quotient 216,1 is the meridional distance sought.

41. CASE V. Given the distances between the same two meridians in different parallels, and also the latitude of one parallel, to find the latitude of the other.

EXAM. *If two ships in the lat. $44^{\circ} 30'$ N. distant from one another 216 miles, should both sail directly south, until their distance is 256 miles; what latitude are they come to?*

By CONSTRUCTION. Fig. 7, Pl. XIII.

From P, with a radius of the co-sine of $44^{\circ} 30'$, the lat. sailed from, describe the arc DE; draw the chord DE=216; and through D and E draw PA, PB; continue DE till DF=256; through F draw FB parallel to PA, meeting PB in B; then an arc described from P, through B and A, will be the parallel of latitude come to.

By COMPUTATION.

As DE, the first dist.	= 216	7,66554
To AB, the second dist.	= 256	2,40824
So PD, the co-f. lat. from	= $44^{\circ} 30'$	<u>9,85324</u>
To PA, the co-f. lat. in	= $32^{\circ} 17'$	<u>9,92702</u>

By the TABLE.

To lat. $44^{\circ} 30'$ find (35) the mer. dist. 42,8; this multiplied by 256, and the product divided by 216, gives 50,72; which (by 36) will be found to be the merid. dist. to $32^{\circ} 17'$, the latitude sought.

42. Other

42.

Other examples to exercise the foregoing cases.

Ex. I. *What is the distance between St. Mary's in lat. $37^{\circ} 00'$ N. long. $25^{\circ} 00'$ W. and Cape Henry in lat. $37^{\circ} 00'$ N. long. $76^{\circ} 23'$ W.?*

As rad. : co-f. lat. $37^{\circ} 00'$: : diff. long. 3083 : dist. 2462.

Ex. II. *A ship from Cape Clear sails west 265 miles; what long. is she come to?*

As co-f. lat. $51^{\circ} 18'$: radius : : merid. dist. 265 : diff. long. 423,8.

Answer. The present longitude is $16^{\circ} 54'$ W.

Ex. III. *A ship having run due east for 3 days, at the rate of 5 knots an hour, finds she has altered her longitude $8^{\circ} 16'$; what parallel of latitude did she sail in?*

As diff. long. 496 : merid. dist. 360 : : rad. : co-f. lat. $43^{\circ} 28'$.

Ex. IV. *Suppose two ships in the parallel of $47^{\circ} 54'$ N. their difference of long. being $9^{\circ} 35'$, should both sail directly south 836 miles; how far were they from each other when they set out, and also after they had run that distance?*

As rad. : co-f. lat. $47^{\circ} 54'$: : diff. long. 575 : first merid. dist. 385,5m.

Now 836 miles = $13^{\circ} 56'$; therefore the lat. come to is $33^{\circ} 58'$.

As rad. : co-f. lat. $33^{\circ} 58'$: : diff. long. 575 : last merid. dist. 476,9 m.

Ex. V. *What is the diff. lat. between two parallels on diff. sides of the equator, when, between the same two meridians, the meridional distance in the northern parallel is $AB=238$ miles, in the southern parallel is $CD=195$ miles, and at the equator is $EQ=352$ miles?*

As diff. long. 352 : north. mer. dist. 238 : : rad. : co-f. lat. $47^{\circ} 27'$ N.

As diff. long. 352 : south. mer. dist. 195 : : rad. : co-f. lat. $56^{\circ} 22'$ S.

Then the sum of these two latitudes, viz. $103^{\circ} 49'$, is the diff. lat. sought.

In this figure 8, Pl. XIII. *p* is the north pole, and *s* is the south pole; but the construction on one side of the equator is sufficient, as is evident by drawing *ed* parallel to *PE*, and *dc* parallel to *EQ*.

The difference of longitude and meridional distances may be considered as tangents to their respective arcs, as well as chords. (II. 185)

Among the natural scales on the Gunter, are two, which used jointly, answer the end of the foregoing table: these are a scale of chords marked *CH*, and a scale of longitude marked *ML*, standing close to one another; they are thus used:

Find the given latitude on the scale of chords, and right against it, in the scale of longitude, is the division expressing the miles of merid. distance in that lat. to one degree of longitude.

Thus against the chord 60° stands 30 miles; the chord 50° stands between 38 and 39 miles: and so of the rest.

SECTION IV.

*Of Middle Latitude, and Mercator's sailings.**Of Middle Latitude sailing.*

43. MIDDLE LATITUDE SAILING is a manner of solving the several cases of globular sailing, by the principles of plane and parallel sailing jointly.

This method, which is not quite accurate, is founded on the following supposition.

44. The departure is reckoned as a meridional distance in that latitude, which is a middle parallel between the latitude sailed from, and the latitude arrived at.

Now although the arithmetical mean of the co-fines of two distant latitudes is not the co-sine of the arithmetical mean of those latitudes; neither is the departure between two places on an oblique rhumb equal to the distance between their meridians in a mean latitude; yet when the parallels of those places are near the equator, or not far distant from one another, in any latitude, the error becomes so small, as not materially to affect the nautical conclusions drawn from the foregoing supposition.

This artifice seems to have been invented on account of the easy manner in which the several cases may be resolved by the Traverse Table, and where a table of meridional parts is wanting. The computations depend on the following rules.

RULE I.

45. If the places are on the same side of the equator, add the latitude sailed from to the latitude arrived at, and take half the sum for the middle latitude; but if they are on different sides, half their difference is the middle latitude.

RULE II.

46. As the co-sine of the middle latitude,	= C.
Is to the radius;	= R.
So is the departure,	= D.
To the difference of longitude.	= L.

RULE III.

47. As the co-sine of the middle latitude,	= C.
Is to the tangent of the course;	= T.
So is the difference of latitude,	= P.
To the difference of longitude.	= L.

The second rule is the same as the first rule in parallel sailing, which is demonstrated at art. 7.

Demonstration

Demonstration of the third rule.

Now co-f. mid. lat. : rad. :: departure : diff. long. (7)
 Therefore rad. $\times$ dep. = co-f. mid. lat. $\times$ diff. long. (II. 162)
 Also diff. lat. : depart. :: rad. : tang. course. (VII. 26)
 Therefore rad. $\times$ dep. = diff. lat. $\times$ tang. course. (II. 162)
 Consequently co-f. mid. lat. $\times$ diff. long. = diff. lat. $\times$ t. course. (II. 46)
 Therefore co-f. mid. lat. : tang. course :: diff. lat. : diff. long. (II. 163)

From rules II. and III. arise the following proportions.

C : R :: D : L.	C : T :: P : L.
L : D :: R : C.	P : L :: C : T.
R : C :: L : D.	

Where the letters signify the names they stand against in the rules.

Of Mercator's sailing.

48. MERCATOR'S SAILING is the art of resolving the several cases of Globular sailing by Plane Trigonometry, with the assistance of a table of meridional parts, or of logarithmic tangents.

The computations herein are performed by the following rules. (15)

49. **RULE I.** Therefore
 As merid. diff. lat. = M. M : L :: R : T.
 To diff. longitude; = L. R : T :: M : L.
 So is the radius, = R. T : R :: L : M.
 To tang. course. = T.

50. **RULE II.** Therefore
 As the prop. diff. lat. = P. P : D :: M : L.
 To the departure; = D. M : L :: P : D.
 So mer. diff. lat. = M.
 To diff. longitude = L.

These rules are demonstrated at Prop. IV.

51. **RULE III.** Therefore
 As diff. log. tang. $\frac{1}{2}$ co-lats. = G. G : N :: L : T.
 To tang of $51^{\circ} 38' 09''$; = N.* N : G :: T : L.
 So is a given diff. long. = L. T : L :: N : G.
 To tang. course. = T

For the demonstration of this analogy, see Prop. XIII. (29)

* The log. tang. of $51^{\circ} 38' 09''$ is 10,10151; its ar. co. is 9,89849. (I. 88)
 The decimal part of this log. tang. answers also to $85^{\circ} 28' 37''$; and to $89^{\circ} 32' 47''$; and to $89^{\circ} 57' 17''$; their indices being 11, 12, 13: So that at either of these angles, the diff of longitude will be shewn by the diff. of the log. tang. of the half co-lats. failed from and come unto; observing that the number of integer places in G becomes one more, for each unit that the index is increased.

GLOBULAR SAILING. Book VIII. PROBLEM I.

52. Given the latitudes of two places :

Required the meridional difference of latitude between those places.

CASE I. When both places are on one side of the equator.

RULE I. The difference of the meridional parts answering to each latitude will give the meridional difference of latitude required.

RULE II. The difference of the log. tangents of the half co-latitudes divided by 12,63, will give the meridional difference of latitude required.

EXAM. I. *What is the meridional difference of latitude between the island of St. Thomas and Gibraltar?*

By the meridional parts.

Gibraltar lat.	36° 05' N.	
St. Thomas's lat.	00 00	
Merid. parts to	36 05	2324
Merid. parts to	00 00	0000
Merid. diff. lat.	=	2324

By the log. tangents.

Co-lat.=53° 55'; $\frac{1}{2}$ co-lat.=26° 57'	
Co-lat.=90 00; $\frac{1}{2}$ co-lat.=45 00	
Log. tang.	10,00000 to 45 00
Log. tang.	9,70638 to 26 57'
	12,63) 29362(2325
	4102
	3130
	6040

EXAM. II. *What is the meridional difference of latitude between the Lizard and Cape Verd?*

By the meridional parts.

C. Verd's lat.	14° 47' N.	
Lizard's lat.	49 57 N.	
Merid. parts to	49 57	3470
Merid. parts to	14 47	897
Merid. diff. lat.	=	2573

By the log. tangents.

Co-lat.=75° 13'; $\frac{1}{2}$ co-lat.=37° 36'	
Co-lat.=40 03; $\frac{1}{2}$ co-lat.=20 01'	
Log. tang.	9,88668 to 37 36'
Log. tang.	9,56166 to 20 01'
	12,63) 32502(2573=m.p.

53. CASE II. When the given places are on different sides of the equator.

RULE I. The sum of the meridional parts answering to each latitude will be the meridional difference of latitude required.

RULE II. The sum of the log. co-tangents, abating the index, of the half co-latitudes, divided by 12,63, will be the meridional difference of latitude required.

EXAM. *What is the meridional difference of latitude between Cape Verd, and the Island of St. Helena?*

By the meridional parts.

C. Verd's lat.	14° 47' N.	
St. Helena	15 55 S.	
Merid. parts to	15 55	968
Merid. parts to	14 47	897
Merid. diff. lat. to	=	1865

By the log. tangents.

Co-lat.=75° 13'; $\frac{1}{2}$ co-lat.=37° 36'	
Co-lat.=74 05; $\frac{1}{2}$ co-lat.=37 02'	
Log. co-t.	0,11332 to 37 36'
Log. co-t.	0,12223 to 37 02'
	12,63) 23555(1865=m.p.

PRO.

PROBLEM II.

54. Given the lat. of one place, and the merid. diff. lat. between that and another place :

Required the latitude of the other place.

CASE I. When the given lat. and merid. diff. lat. have like names.

RULE I. To the merid. parts of the given lat. add the given meridional diff. lat. ; seek the sum in the table of meridional parts, and the corresponding degrees and minutes give the latitude sought.

RULE II. Multiply the given merid. diff. lat. by 12,63 ; subtract the product, rejecting all to the right of the 5th decimal place *, from the log. tang. of the given half-co-lat. ; seek the degrees to the remainder among the log. tang. and these deg. doubled give the co-lat. required.

EXAM. A ship from the lat. $14^{\circ} 43' N.$ sails northward till she finds her merid. diff. lat. is 2578 ; what latitude is she come to ?

By meridional parts.

To the lat. $14^{\circ} 43' N.$
The merid. parts = 893 N.
Add merid. diff. lat. = 2578 N.
The sum is = 3471

Which answers to $49^{\circ} 58' N.$
The latitude sought.

By log. tangent.

The co-lat. is $75^{\circ} 17'$; $\frac{1}{2}$ co-lat. $37^{\circ} 38'$.
And 2578 multiplied by 12,63, gives
32560, 14.
From 9,88707 = log. tang. $37^{\circ} 38'$
Take 0,32560

Leaves 9,56147 = log. tang. $20^{\circ} 01'$.

Which doubled is $40^{\circ} 02'$.

Whose comp. is $49^{\circ} 58'$ = lat. sought.

55. CASE II. When the given lat. and meridional diff. lat. have unlike names.

RULE I. Take the difference between the meridional parts of the given latitude and the meridional diff. lat. the remainder found in the table of meridional parts will give the latitude sought.

RULE II. Multiply the given meridional diff. lat. by 12,63 ; add the product to the log. tan. of the given half co-latitude, the degrees answering to the sum, considered as a tangent, being doubled, gives the co-latitude required.

EXAM. A ship from the latitude $49^{\circ} 57' N.$ sails southward till her meridional diff. lat. is 2578 ; what latitude is she come to ?

By meridional parts.

To the lat. $49^{\circ} 57' N.$
The merid. parts = 3470 N.
Subt. merid. diff. lat. = 2578 S.
Remain merid. parts = 892

Which answers to $14^{\circ} 42' N.$
The latitude come to.

By log. tangents.

Co-lat. $40^{\circ} 03'$; $\frac{1}{2}$ co-lat. $20^{\circ} 01'$.
And $2578 \times 12,63 = 32560, 14.$
To 9,56146 = log. tang. $20^{\circ} 01'$.
Add 0,32560

Sum 9,88706 = log. tang. $37^{\circ} 01'$.

Which doubled is $75^{\circ} 16'$.

Whose comp. is $14^{\circ} 44'$ = lat.

* That is, rejecting all below the number of places in the tables used.

PROBLEM III.

56. Given the latitudes and longitudes of two places :
Required their bearing and distance.

EXAM. *What is the course and distance from Cape Clear in Ireland, to the island of St. Mary, one of the Azores ?*

By MIDDLE LATITUDE SAILING.

C. Clear's lat.	51° 18' N.	Long.	9° 50' W.
St. Mary's lat.	37 00 N.	Long.	25 00 W.
Diff. lat.	<u>14 18=858 m.</u>	Diff. long.	<u>15 10=910 m.</u>

Sum of the lat. 88 18; Midd. lat. 44° 09'; Co-mid. lat. 45° 51'.

By CONSTRUCTION. Fig. 9. Plate XIII.

Draw the meridian AD; describe the quadrant A *m p* with the sine of 90°, and the arc EF with the co-sine of the middle latitude. Make the chord *mB* equal to 910, the diff. longitude; draw AB cutting the arc EF in F, and draw the chord EF. Make AD equal to 858, the diff. lat. draw DC parallel to A *p* and equal to EF: and draw AC.

Then AC is the distance, and the angle DAC is the course.

By COMPUTATION.

For the Course.			For the Distance.		
P : L :: C : T.	(47)	fin. ∠ C	AD :: R : AC.		
As diff. lat. = 858	7,06651	As co-s. cour. = 37° 16'	0,09918		
To diff. long. = 910	2,95904	To diff. lat. = 858	2,93349		
So co-s. m. lat. = 44° 09'	9,85583	So rad. = 90° 00'	10,00000		
To tang. cour. = 37 16	<u>9,88138</u>	To dist. = 1078	<u>3,03267</u>		

By the TRAVERSE TABLE.

1st. With the co-mid. lat. found among the degrees, and the diff. longitude, or some part of it (if the whole is too large), taken among the distances, find the departure, or some part of it, in its column:

Observing to multiply this depart. by the same number the diff. longitude was divided by.

2d. With the diff. lat. and dep. together, or their like parts, find the course among the degrees, and the distance in its column.

Let the diff. long. 910 be broken into parts; viz. into 100 taken nine times, and into 10: And as the co-mid. lat. is 45° 51', or 45° $\frac{5}{8}$; proceed thus:

The departures to 100, in the columns of 45° and 46°, are 70,7 and 71,9; the diff. is 1,2; $\frac{5}{8}$ parts thereof is, 1,0; which added to 70,7 makes 71,7; for the dep. to 100; and for 900 it will be 645,3. Also, the departures to 10 in the columns of 45° and 46°, are 7,07 and 7,19; $\frac{5}{8}$ of their diff. 1,0, and this with 7,07 makes 7,17 the dep. to 10; and the whole dep. = 652,5.

Now take $\frac{1}{20}$ of the diff. lat. 858, and of the dep. 65,25, viz. 42,9 and 32,62, these will be found together under 37° 15' for the course; and
between

between 53 and 54 dist.; suppose 53,9; which taken 20 times gives 1078 for the distance.

By MERCATOR'S SAILING.					
57.	C. Clear long.	9° 50' W.	Lat.	51° 18'	Mer. parts 3597
	St. Mary's long.	25 00 W.	Lat.	37 00	Mer. parts 2393
	Diff. long.	15 10	Diff. lat.	14 18	Mer. diff. lat. 1204
	Or 910 miles.		Or 858 miles.		

By CONSTRUCTION. Fig. 17. Plate XIII.

Draw the meridian AB, and describe the quadrant A m p; make AD = 858, the proper diff. lat. and AB = 1204, the meridional diff. lat.; draw DC, BE, parallel to A p; make BE equal to 910, the diff. long. and draw AE.

Then A is the place of Cape Clear, c that of St. Mary's; AC is the distance, CD the departure, and the angle DAC is the course.

COMPUTATION by Meridional Parts.

For the Course.			For the Distance.		
M : L :: R : T. (49)			fin. $\angle C$: AD :: R : AC:		
As mer. d. lat. = 1204	6,91937		As co-f. cour. = 37° 05'	0,09813	
To diff. long. = 910	2,95904		To prop. d. lat. = 858	2,93349	
So rad. = 45° 00'	10,00000		So rad. = 90° 00'	10,00000	
To tan. cour. = 37 05	9,87841		To dist. = 1076	3,03162	

COMPUTATION by Logarithmic Tangents.

C. Clear's lat. 51° 18'	Co-lat. 38° 42'.	$\frac{1}{2}$ co-lat. 19° 21'.
St. Mary's lat. 37 00	Co-lat. 53 00.	$\frac{1}{2}$ co-lat. 26 30.
To $\frac{1}{2}$ co-lat. 26° 30', its log. tang. =	9,69774	
To $\frac{1}{2}$ co-lat. 19 21, its log. tang. =	9,54552	
Difference =	1522,2 = G.	

For the Course.			For the Distance.	
S : N :: L : T. (51)			The distance will be the same as in the former computation; for the diff. of a min. in the course will not cause a diff. of a mile in the distance of the two places.	
As G 1522	6,81759			
To N 10,10151				
So diff. long. 910	2,95904			
To tang. cour. 37° 04'	9,87814			

By the TRAVERSE TABLE.

Seek the meridional diff. lat. and diff. long. together, as if they were diff. lat. and departure, and the course is given among the degrees.

Then with the course and proper diff. lat. find the distance.

Thus taking $\frac{1}{20}$ th of 1204 and 910, viz. 60,2 and 45,5; they will be found together under 37° 00' for the course.

And taking $\frac{1}{20}$ th of the diff. lat. 858, viz. 42,9, and the course 37° 0', gives about 53,8 for the dist. which taken 20 times gives 1076 dist.

PRO.

PROBLEM IV.

58. Given the bearing and latitudes of two places.
Required the distance and difference of longitude.

EXAM. *A ship which had taken her departure from a place in latitude $37^{\circ} 00' N.$ longitude $22^{\circ} 56' W.$ steers $N. 33^{\circ} 19' E.$; and cloudy weather coming on, she got no observation till eight days after, and then found herself in latitude $51^{\circ} 18' N.$: Required her true distance and present longitude.*

By MIDDLE LATITUDE SAILING.

Depart. lat.	$37^{\circ} 00' N.$	Sum of the latitudes	$88^{\circ} 18'$
Present lat.	$51^{\circ} 18' N.$	Mid. lat.	$44^{\circ} 09'$
Diff. lat.	$14^{\circ} 18' = 858 m.$	Co mid. lat.	$45^{\circ} 51'$

By CONSTRUCTION. Fig. 10. Plate XIII.

Draw the meridian $AD = 858$, the diff. lat. describe the quadrant Amp ; make mc equal to $33^{\circ} 19'$, the course: draw DC parallel to Ap meeting the rhumb AC , drawn through c , in mc : with the sine of the co-mid. lat. $45^{\circ} 51'$, describe the arc EF , in which apply the departure DC , from E to F : draw AB through F , and draw the chord mB .

Then is AC the distance run, and mB the diff. longitude.

By COMPUTATION.

For the distance.			For the diff. longitude.		
$\sin. \angle C : AD :: R : AC.$			$C : T :: P : L. (47)$		
As co-f. cour. = $33^{\circ} 19'$	0.07798		As co-f. m. lat. = $44^{\circ} 09'$	0.14417	
To diff. lat. = 858	2.93349		To tang. cour. = $33^{\circ} 19'$	9.81776	
So rad. = $90^{\circ} 00'$	10.00000		So diff. lat. = 858	2.93349	
To dist. = 1027	3.01147		To diff. long. = 786	2.89542	

Now $22^{\circ} 56' W. =$ Dep. long.
 $60)786(13 \ 06 E. =$ Diff. long.

$9 \ 50 W. =$ Pres. long.

By the TRAVERSE TABLE.

1st. With the course among the degrees, and the diff. lat. in its proper column, find the departure and distance, in their columns.

2d. With the co-mid. lat. among the degrees, and the departure in its column, find the diff. long. among the distances.

Thus taking the $\frac{1}{2}$ of diff. lat. 858 , viz. 42.9 ; with it, and the course $33\frac{1}{2}^{\circ}$, the departure will be found 28.1 , and the dist. 51.3 ; each being multiplied by 20 , gives 562 for the departure, and 1026 for the distance.

The co-mid. lat. $45^{\circ} 51'$, or $45\frac{5}{8}$ degrees, and $28.1 = \frac{1}{2}$ of the departure, will give 39.5 in the column of distances; which being multiplied by 20 , gives 790 for the difference of longitude.

59. By

By MERCATOR'S SAILING.

59. Departed lat.	37° 00' N.	Mer. parts	2393
Present lat.	51 18 N.	Mer. parts	3597
Diff. lat.	14 18 = 858 m.	Mer. diff. lat.	1204

CONSTRUCTION. Fig. 18. Plate XIII.

Draw a meridian AB, in which take AB=1204, the mer. diff. lat. and AD=858, the proper diff. lat. Describe the quadrant A m p, and take mc=33° 19', the course: through B and D, draw BE, DC, parallel to A p, meeting the rhumb drawn through A and c, in the points E, C.

Then is AC the distance, and BE the diff. longitude.

COMPUTATION by Meridional Parts:

For the distance.			For the diff. longitude.		
fin. $\angle$ DCA :	AB ::	R : AC.	R :	T ::	M : L. (49)
As co-f. cour. =	33° 19'	0,07798	As rad. =	90° 00'	10,00000
To diff. lat. =	858	2,93349	To tang. cour. =	33 19	9,81776
So radius =	90° 00'	10,00000	So m. diff. lat. =	1204	3,08063
To dist. =	1027	3,01147	To diff. long. =	791,4	2,89839

Now if from 22° 56' W. = Dep. long.
There be taken 60)791 (13 11 E. = Diff. long.

Then 9 45 W. = Pref. long.

COMPUTATION by Logarithmic Tangents.

Departed lat.	37° 00' N.	Co-lat.	53° 00'	$\frac{1}{2}$ co-lat.	26° 30'.
Present lat.	51 18 N.	Co-lat.	38 42	$\frac{1}{2}$ co-lat.	19 21.

To $\frac{1}{2}$ co-lat. 26° 30', its log. tang.	=	9,69774
To $\frac{1}{2}$ co-lat. 19 21, its log. tang.	=	9,54552

Difference = 1522,2=G.

For the distance.		For the diff. longitude.	
fin. $\angle$ DCA :	AB ::	R : AC.	N : G :: T : L. (51)
The distance is found as above.		As N =	9,89849
		To G =	1522 3,18241
		So tang. cour. =	33° 19' 9,81776
		To diff. long. =	791,8 2,89866

By the TRAVERSE TABLE.

With the course among the degrees, and the diff. lat. found in the column of lat. find the distance in its column.

With the course among the degrees, and the mer. diff. lat. in the column of lat. find the corresponding dep. and take it for the diff. long.

Now $\frac{1}{20}$ th of 858, the diff. lat. and of 1204, the mer. diff. lat. are 42,9 and 60,2. Then, under 33° 15', the diff. lat. 42,9 falls between 51 and 52 in the distances, take it 51,5; which multiplied by 20 gives 1030 for the distance.

And under 33° 15', the mer. diff. lat. falls against 39,48 of departure, which multiplied by 20 gives 789,6 for the diff. longitude.

PRO-

PROBLEM V.

60. Given one latitude, course and distance:
Required the other latitude and diff. longitude.

EXAM. A ship takes her departure from a place in lat. $51^{\circ} 18' N.$ long. $9^{\circ} 50' W.$; and steers $S. 33^{\circ} 08' W.$ till she has run 1024 miles: Required her present latitude and longitude.

By MIDDLE LATITUDE SAILING.

By CONSTRUCTION. Fig. II. Plate XIII.

Draw a meridian AD , and describe the quadrant Amp ; make the arc $mc = 30^{\circ} 08'$, the course: in the rhumb drawn through c , take $AC = 1024$, the distance: draw CD parallel to Ap , meeting AD in D .

By COMPUTATION.

For the diff. latitude.			Now $51^{\circ} 18' N. =$ Dep. lat.	
$R : AC :: \sin. \angle C : AD.$			$60) 857(14$	$17 S. =$ Diff. lat.
As rad. $= 90^{\circ} 00'$	10,00000			
To dist. $= 1024$	3,01030		37	01 N. = Pref. lat.
So co-f. cour. $= 33^{\circ} 8'$	9,92293		88	19 = Sum of the lats.
To diff. lat. $= 857,5$	2,93323		44	09 = Mid. lat.
			45	51 = Co-m. lat.
For the diff. longitude.			Then in the arc EF , described with the sin. co-mid. lat. $45^{\circ} 51'$, apply CD from E to F : through F draw AB , cutting the arc mc in B ; then, mB being drawn, will be the diff. long. sought.	
$As c : T :: P : L.$				
As co-f. m. lat. $= 44^{\circ} 09'$	0,14417			
To tang. cour. $= 33^{\circ} 08'$	9,81473			
So diff. lat. $= 857,5$	2,93323			
To diff. long. $= 780,1$	2,89213			
Now $9^{\circ} 50' W. =$ Dep. long.				
$60) 780(13$				
$00 W. =$ Diff. long.				
22				
$50 W. =$ Pref. long.				

By the TRAVERSE TABLE.

With the course found among the degrees, and the distance in its column, find the dep. and diff. lat.; and hence find the other lat.

Seek the co-mid. lat. among the degrees, and the dep. in its column; then the corresponding dist. is the diff. long. sought.

Thus. Under the course $33^{\circ} 15'$, and against the dist. 51,2, which is the 20th part of 1024, stands lat. 42,7; dep. 28.

Then $42,7 \times 20 = 854$ m. $= 14^{\circ} 14'$, the diff. lat.

Hence the pref. lat. is $37^{\circ} 04' N.$; and the co-mid. lat. $45^{\circ} 49'$.

Again. Over the degrees $45^{\circ} 40'$, the nearest dep. to 28 stands against 39 in the distances.

Then $39 \times 20 = 780$ m. the diff. longitude.

61. By

By MERCATOR'S SAILING.

61. CONSTRUCTION. Fig. 19. Plate XIII.

Draw the meridian AB, describe the quadrant A m p; make the arc m c = 33° 08', the course. In the rhumb AC drawn through c, take AC = 1024 miles, the dist.; and draw CD parallel to A p.

COMPUTATION by Meridional Parts.

For the diff. latitude.

As rad. : AC :: sin. ∠ C : AD.	Now 51° 18' N. = Dep. lat.
As rad. = 90° 00' 10,00000	60) 857 (14 17 S. = Diff. lat.
To dist. = 1024 3,01030	37 01 N. = Pres. lat.
So co-f. cour. = 33° 08' 9,92293	
To pro. diff. lat. = 857,5 2,93323	To 51° 18' merid. parts = 3597
	To 37 01 merid. parts = 2394

For the diff. longitude.

As R : T :: M : L.	
As rad. = 90° 00' 10,00000	Make AB = 1203; through B draw
To tang. cour. = 33 08 9,81473	BE parallel to A p, meeting AC con-
So mer. d. lat. = 1203 3,08026	tinued in E; then BE is the diff.
To diff. long. = 785,2 2,89499	longitude.
Now 9° 50' W. = Dep. long.	
60) 785 (13 05 W. = Diff. long.	
22 55 W. = Pres. long.	

COMPUTATION by Logarithmic Tangents.

The diff. lat. and present lat. being found as above.

Dep. lat. 51° 18' Co-lat. 38° 42' $\frac{1}{2}$ co-lat. 19° 21'
Pres. lat. 37 01 Co-lat. 52 59 $\frac{1}{2}$ co-lat. 26 29 $\frac{1}{2}$
To $\frac{1}{2}$ co-lat. 26° 29 $\frac{1}{2}$ its log. tang. = 9,69758
To $\frac{1}{2}$ co-lat. 19 21, its log. tang. = 9,54552
Difference = 1520.6 = G.

As N : G :: T : L.	Now 9° 50' W. = Dep. long.
As N = 1521 9,89849	60) 786 (13 06 W. = Diff. long.
To G = 33° 08' 3,18213	22 56 W. = Pres. long.
So tan. cour. = 33° 08' 9,81473	
To diff. long. = 785,9 2,89535	

By the TRAVERSE TABLE.

With the course and distance, find the diff. latitude.

From thence find the present lat. and the mer. diff. latitude.

With the course, and the mer. diff. lat. taken in the column of lat. find the corresponding dep. which will be the diff. longitude.

Thus $\frac{1}{2}$ th of the dist. 1024 is 51,2. Then under the course 33° 15', against 51,2 among the distances, stands 42,7 in col. of lat. And 42,7 × 20 gives 854; so the diff. lat. is 14° 14'; the present lat. is 37° 04' N. and the mer. diff. lat. is 1200; $\frac{1}{2}$ th of which is 60,0.

To the course 33° 15', against lat. 60,0, or its nearest 60,21, stands 39,48; which multiplied by 20 gives 789,6 for the diff. long. required.

PROBLEM VI.

62. Given the latitudes of two places, and their distance:
Required their bearing, and difference of longitude.

EXAM. A ship in lat. $51^{\circ} 18' N.$ long. $22^{\circ} 06' W.$, is bound to a place in the SE. quarter, distant 1024 miles, and in lat. $37^{\circ} 00' N.$: what is her direct course, and how much must she alter her long. to arrive at the desired port?

By MIDDLE LATITUDE SAILING.

Lat. from	$51^{\circ} 18' N.$	Sum of the latitudes	$88^{\circ} 18'$
Lat. to	$37^{\circ} 00' N.$		
		Middle latitude	$44^{\circ} 09'$
Diff. lat.	$14^{\circ} 18' = 858 \text{ miles.}$	Co-middle latitude	$45^{\circ} 51'$

By CONSTRUCTION. Fig. 12. Plate XIII.

Draw the meridian $AD = 858$ miles; describe the quadrant Amp : from A , with 1024 miles, the given distance, cut DC , drawn parallel to Ap , in C ; draw AC . In the arc EF , described with the sine of $45^{\circ} 51'$, the co-middle lat., apply the departure DC from E to F ; through F draw AB , and draw the chord Bm .

Then the course is measured by the arc mc ; and the diff. long. by the line mB .

By COMPUTATION.

For the course.			For the diff. longitude.		
$AC : \text{rad.} :: AD : \sin. \angle C.$			$C : T :: P : L.$		
As dist. = 1024	6,98970		As co-f. m. lat. = $44^{\circ} 09'$	0,14417	
To rad. = $90^{\circ} 00'$	10,00000		To tan. cour. = $33^{\circ} 05'$	9,81390	
So diff. lat. = 858	2,93349		So diff. lat. = 858	2,93349	
To co-f. cour. = $33^{\circ} 05'$	9,92319		To diff. long. = 779	2,89156	
			Now $22^{\circ} 06' W.$ = Long. from.		
Course SE. b. S. nearly.			$60) 779 (12^{\circ} 59'$ E. = Diff. long.		
			$9^{\circ} 07' W.$ = Pref. long.		

By the TRAVERSE TABLE.

With the distance and diff. lat. in their columns, find the course among the degrees, and the dep. in its column.

With the co-middle lat. among the degrees, and the dep. in its column, find the diff. long. among the distances.

Thus. To the dist. 64 ($= \frac{1024}{16}$), and the lat. $53,62$ ($= \frac{858}{16}$) the course is $33^{\circ} 00'$; and the dep. 34,86.

The co-mid. lat. 46° (the nearest to $45^{\circ} 51'$), the dep. 34,86 (falling between 34,53 and 35,24, belonging to the distance 48 and 49), gives 48,5 in the col. of distances; which mult. by 16 gives 776 for the diff. long.

Note. $\frac{1}{16}$ th of the numbers was taken rather than $\frac{1}{20}$ th, because 16 divides 1024 without a fraction; and it is more convenient to seek a dist. in whole numbers, than with a fraction annexed.

63. By

63.

By MERCATOR'S SAILING.

Lat. from	51° 18' N.	Mer. parts	=	3597
Lat. to	37 00 N.	Mer. parts	=	2393
Diff. lat.	14 18 = 858 m.	Mer. diff. lat.	=	1204

By CONSTRUCTION. Fig. 20. Plate XIII.

In the meridian AB, take AB=1204, the meridional diff. lat. and AD=858, the proper diff. lat.; describe the quadrant A m p; from A, with the distance 1024, cut DC, drawn parallel to Ap, in C; draw AC, and continue it until it meets BE, drawn parallel to A p in E.

Then BE=diff. long. and arc m c measures the course.

COMPUTATION by Meridional Parts.

For the course.			For the diff. longitude.		
AC : rad. :: AD : f. $\angle$ ACD.			Rad. : T :: M : L.		
As diff. = 1024	6,98970		As rad. = 90° 00'	10,00000	
To rad. = 90° 00'	10,00000		To tang. cour. = 33 05	9,81390	
So p. diff. lat. = 858	2,93349		So m. diff. lat. = 1204	3,08063	
To co-f. cour. = 33° 05'	9,92319		To diff. long. = 784,4	2,89453	
Course SE. by S. nearly.			Now 22° 06' W. = Long. from.		
			60) 784 (13 04 E. = Diff. long.		
			9 02 W. = Long. to.		

COMPUTATION by Logarithmic Tangents.

Depart. lat. 51° 18'.	Co-lat. 38° 42'.	$\frac{1}{2}$ co-lat. 19° 21'.
Lat. bound to 37 00.	Co-lat. 53 00.	$\frac{1}{2}$ co-lat. 26 30.
To $\frac{1}{2}$ co-lat. 26° 30', its log. tang. =	9,69774	
To $\frac{1}{2}$ co-lat. 19 21, its log. tang. =	9,54552	
Difference =	1522,2 = G.	

For the course.

AC : rad. :: AD : f. $\angle$ ACD.

Course is S. 33° 05' E. as above.

For the diff. longitude.

N : G :: T : L.	
As N =	9,89849
To G = 1522	3,18211
So tan. cour. = 33° 05'	9,81390
To diff. long. = 784,9	2,89453

By the TRAVERSE TABLE.

With the distance and diff. lat. in their columns, find the course among the degrees.

With the course among the degrees, and the meridional diff. lat. in the column of latitude, find the diff. long. in the column of departure.

The course, found as before, is 33° 00'.

And $\frac{1}{20}$ th of the meridional diff. lat. viz. 60,2 found under 33°, in the column of latitude, the nearest corresponding departure is 39,21; which multiplied by 20 gives 784,2 for the diff. longitude.

PROBLEM VII.

64. Given the latitudes of two places, and the departure :
Required the course, distance, and difference of longitude.

EXAM. *A ship from the latitude $37^{\circ} 00' N.$, longitude $48^{\circ} 20' W.$, sails between the N. and E., and being come to the latitude $51^{\circ} 18' N.$, finds she has made 564 miles of departure: what was her direct course, distance run, and present longitude?*

By MIDDLE LATITUDE SAILING.

Present lat.	$51^{\circ} 18' N.$	Sum of the latitudes	$88^{\circ} 18'$
Departed lat.	$37^{\circ} 00' N.$		
		Mid. lat.	$44^{\circ} 09'$
Diff. lat.	$14^{\circ} 18' = 858 \text{ m.}$	Co-mid. lat.	$45^{\circ} 51'$

By CONSTRUCTION. Fig. 13. Plate XIII.

In a meridian line, take $AD = 858 \text{ m.}$, the diff. lat. Describe the quadrant $A m p$, and parallel to $A p$ draw $DC = 564 \text{ m.}$ the departure; also draw the distance AC ; in the arc EF , described with the sine of the co-mid. lat. $45^{\circ} 51'$, apply the chord EF equal to DC ; through F draw AB ; then the chord $m B$ will be the diff. long., and the arc $m c$ measures the course.

By COMPUTATION.

To find the course.			To find the distance.		
$AD : DC :: \text{rad.} : \tan \angle DAC.$			$\sin \angle DAC : DC :: \text{rad.} : AC.$		
As diff. lat. = 858	7,06651		As fin. cour. = $33^{\circ} 19'$	0,26022	
To depart. = 564	2,75128		To depart. = 564	2,75128	
So rad. = $90^{\circ} 00'$	10,00000		So rad. = $90^{\circ} 00'$	10,00000	
To tang. cour. = 33 19	9,81779		To dist. = 1027	3,01150	

To find the diff. longitude.

$C : R :: D : L.$			$Orc : T :: P : L.$		
As co-f. m. lat. = $44^{\circ} 09'$	0,14417		Now $48^{\circ} 20' W. = \text{Dep. long.}$		
To rad. = 90 00	10,00000		$60) 786 (13^{\circ} 06' E. = \text{Diff. long.}$		
So depart. = 564	2,75128				
To diff. long. = 786	2,89545		35 14 W. = Pres. long.		

Course NE. b. N. nearly.

By the TRAVERSE TABLE.

The diff. lat. and departure being found together, will give the course among the degrees, and the distance in its column.

With the co-mid. lat. among the degrees, and the departure in its column, find the diff. longitude among the distances.

Now $\frac{1}{20}$ th of 858, the diff. lat., and of 564, the dep., are 42,9 and 28,2. The nearest numbers to these are found together under the course $33^{\circ} 30'$, and to the distance 51,2; which, multiplied by 20, gives 1024.

Also the departure 28,2 being found to the co-mid. latitude 46° , gives 39,2; which multiplied by 20 gives 784 for the diff. longitude.

65. By

65. By MERCATOR'S SAILING.

Present lat.	51° 18' N.	Mer. parts	3597
Departed lat.	37 00 N.	Mer. parts	2393
Diff. lat.	14 18=858 m.	Mer. diff. lat.	1204

By CONSTRUCTION. Fig. 21. Plate XIII.

In a meridian line take $AB=1204$ m., the meridional diff. lat.; and $AD=858$ m., the prop. diff. lat. Describe the quadrant Amp ; through D draw DC parallel to Ap , and make $DC=564$ m., the dep. Through C , draw AE meeting BE , drawn parallel to Ap .

Then is AC the distance, BE the diff. longitude; and the arc mc measures the course.

COMPUTATION by Meridional Parts.

For the course.			For the distance.		
$AD : DC :: \text{rad.} : t. \angle DAC.$			$\text{Sin. } \angle DAC : DC :: \text{rad.} : AC.$		
As diff. lat. = 858	7,06651		As fin. cour. = 33° 19'	0,26022	
To depart. = 564	2,75128		To depart. = 564	2,75128	
So rad. = 90° 00'	10,00000		So rad. = 90° 00'	10,00000	
To tang. cour. = 33 19	9,81779		To dist. = 1027	3,01150	

For the diff. long. $P : D :: M : L.$			$Or R : T :: M : L.$		
As prop. diff. lat. = 858	7,06651		Now 48° 20' W. =	Dep. long.	
To depart. = 564	2,75128		60) 791 (13 11 E. =	Diff. long.	
So mer. diff. lat. = 1204	3,08063				
To diff. long. = 791,5	2,89842		35 09 W. =	Pres. long.	

Course NE. b. N. nearly.

COMPUTATION by Logarithmic Tangents.

Departed lat.	37° 00' N.	Co-lat.	53° 00'.	$\frac{1}{2}$ co-lat.	26° 30'.
Present lat.	51 18 N.	Co-lat.	38 42.	$\frac{1}{2}$ co-lat.	19 21.

To $\frac{1}{2}$ co-lat. 26° 30', its log. tang.	=	9,69774
To $\frac{1}{2}$ co-lat. 19 21, its log. tang.	=	9,54552

$$\text{Difference} = 1522,2 = G.$$

The course and distance are found as above,

For the diff. longitude.		
$N : G :: T : L.$		
As N =		9,89849
To G. = 1522		3,18241
So tang. cour. = 33° 19'		9,81776
To diff. long. = 791,9		2,89866

By the TRAVERSE TABLE.

The course, found as before, is 33° 30'; under which, against 60,2 ($=\frac{1}{20}$ th of the mer. diff. lat.) in the column of latitude, stands 39,74 in the column of departure. Then $39,74 \times 20 = 794,8$, the diff. longitude.

PROBLEM VIII.

66. Given one latitude, the course, and departure :
Required the other latitude, distance, and diff. longitude.

EXAM. A ship from the latitude $51^{\circ} 18' N.$, longitude $9^{\circ} 50' W.$, sails $S. 33^{\circ} 19' W.$, until her departure is 564 miles; required her present latitude, longitude, and distance.

By MIDDLE LATITUDE SAILING.

CONSTRUCTION. Fig. 14. Plate XIII.

Draw a meridian line AD ; describe the quadrant Amp ; make $Aa = 564$, the departure, and the arc $mc = 33^{\circ} 19'$, the course; through c draw the rhumb AC meeting $a c$, drawn parallel to AD , in c ; and draw cd parallel to Ap .

By COMPUTATION.

For the diff. latitude.		Now $51^{\circ} 18' N. =$ Dep. lat.	
$\text{Sin. } \angle DAC : CD :: \text{fin. } \angle ACD : AD,$		60)858(14 18 S. =	Diff. lat.
As fin. cour. = $33^{\circ} 19'$	0,26022		
To depart. = 564	2,75128	37 00 N. =	Present lat.
So cof. cour. = $33^{\circ} 19'$	9,92202	88 18 =	Sum of the lat.
To diff. lat. = 858	2,93352	44 09 =	Middle lat.
		45 51 =	Co-m. lat.

Then in the arc EF , described with the fine of $45^{\circ} 51'$, apply CD from E to F ; through F draw AB ; and draw the diff. longitude Bm .

To find the distance.		To find the diff. longitude.	
$\text{Sin. } \angle DAC : CD :: \text{rad.} : AC.$		$As c : \text{rad.} :: D : L.$	
As fin. course = $33^{\circ} 19'$	0,26022	As cof. mid. lat. = $44^{\circ} 09'$	0,14417
To departure = 564	2,75128	To rad. = $90^{\circ} 00'$	10,00000
So rad. = $90^{\circ} 00'$	10,00000	So departure = 564	2,75128
To distance = 1027	3,01150	To diff. long. = 786	2,89545

Now $9^{\circ} 50' W. =$ Dep. long.
60)786(13 06 W. = Diff. long.

22 56 W. = Present long.

By the TRAVERSE TABLE.

With the course $33^{\circ} 15'$ (the nearest to $33^{\circ} 19'$) and the departure 28,2 ($= \frac{1}{20}$ th of 564) in its column, find the diff. of lat. (42,53) in the column of latitude, and in the column of distance find the distance 51,2.

Then $42,53 \times 20 = 850,6$; and $51,2 \times 20 = 1024$.

Hence the present lat. is $37^{\circ} 07' N.$, and the co-mid. lat. $45^{\circ} 48'$.

The co-mid. lat. $45^{\circ} 40'$ and departure 28,2 gives 30,2 in the column of distances, which multiplied by 20 gives 784, for the diff. of longitude.

67. By

67.

By MERCATOR'S SAILING.

By CONSTRUCTION. Fig. 22. Plate XIII.

Draw a meridian line AB ; describe the quadrant Amp ; make $Aa = 564$, and the arc $mc = 33^\circ 19'$; draw ac parallel to AB meeting the rhumb AC , drawn through c , in c ; and draw the departure CD parallel to Aa .

COMPUTATION by Meridional Parts.

For the diff. latitude.		Now $51^\circ 18' N.$	=	Dep. lat.
$\sin \angle DAC : CD :: \sin \angle DCA : AD.$		$60) 858 (14 \ 18 \ S.$	=	Diff. lat.
As fin. cour. = $33^\circ 19'$	0,26022	$37 \ 00 \ N.$	=	Pres. lat.
To depart. = 564	2,75128	To $51^\circ 18'$ merid. parts	=	3598
So co-f. cour. = $33^\circ 19'$	9,92202	To 37 00 merid. parts	=	2394
To diff. lat. = 858	2,93352	Merid. diff. lat.	=	1204

Then make $AB = 1204$; draw BE parallel to Aa , meeting AC continued, in E ; and BE is the diff. of longitude.

To find the distance.

As fin. $\angle DAC : DC :: \text{rad.} : AC.$	
As fin. cour. = $33^\circ 19'$	0,26022
To depart. = 564	2,75128
So rad. = $90^\circ 00'$	10,00000
To distance = 1027	3,01150

To find the diff. longitude.

$P : D :: M : L.$	
As p. diff. lat. = 858	7,06651
To depart. = 564	2,75128
So mer. diff. lat. = 1204	3,08063
To diff. long. = 791,4	2,89843

Now $9^\circ 50' W.$ = Dep. long.
 $60) 791 (13 \ 11 \ W.$ = Diff. long.

23 01 W. = Pres. long.

COMPUTATION by Logarithmic Tangents.

Find the diff. latitude and present latitude as above.

Then, Dep. lat. $51^\circ 18'$. Co-lat. $38^\circ 42'$. $\frac{1}{2}$ co-lat. $19^\circ 21'$.
 Pres. lat. $37 \ 00$. Co-lat. $53 \ 00$. $\frac{1}{2}$ co-lat. $26 \ 30$.

To $\frac{1}{2}$ co-lat. $26^\circ 30'$, its log. tang. is = 9,69774
 To $\frac{1}{2}$ co-lat. $19 \ 21$, its log. tang. is = 9,54552

Difference = 1522,2 = G.

To find the diff. longitude.

As N =	9,89849
To G = 1522	3,18241
So tang. cour. = $33^\circ 19'$	9,81776
To diff. long. = 791,8	2,89866

$N : G :: T : L.$

The distance and present longitude may be found as above.

By the TRAVERSE TABLE.

Find, as before, the diff. lat. = 851; and the distance = 1024.

Then the present lat. is $37^\circ 07' N.$; and the mer. diff. lat. is 1197, 1st of which is 59,85.

Now under the course $33^\circ 15'$, and against 60,21, the nearest to 59,85 in the column of latitude, stands in the column of dep. 39,48; which, multiplied by 20, gives 789,6 for the diff. longitude.

P 4

PROBLEM

PROBLEM IX.

68. Given one latitude, the distance, and departure :
Required the other latitude, course, and diff. longitude.

EXAM. A ship from the latitude $37^{\circ} 00' N.$, longitude $9^{\circ} 02' W.$, having sailed between the N. and W. 1027 miles, reckons she has made 564 miles of departure; what was her direct course, and the present latitude and longitude?

By MIDDLE LATITUDE SAILING.

By CONSTRUCTION. Fig. 15. Plate XIII.

Draw the meridian line AD; describe the quadrant A m p; make A a = 564 m.; from A, with 1027, the distance, cut a c, drawn parallel to AD, in c; draw AC, and draw the departure CD parallel to A p.

By COMPUTATION.

To find the course.			To find the diff. latitude.		
AC : rad. :: CD : sin. $\angle DAC$.			Rad. : AC :: sin. $\angle DCA$: AD.		
As dist. = 1027	6,98843		As rad. = $90^{\circ} 00'$	10,00000	
To rad. = $90^{\circ} 00'$	10,00000		To dist. = 1027	3,01157	
So depart. = 564	2,75128		So co-f. cour. = $33^{\circ} 19'$	9,92202	
To fin. cour. = $33^{\circ} 19'$	9,73971		To diff. lat. = 858,2	2,93359	
Now $37^{\circ} 00' N.$ = Dep. lat.			Sum of the latitudes $88^{\circ} 18'$		
60) 858 (14 18 N. = Diff. lat.			Mid. lat. 44 09		
51 18 N. = Pref. lat.			Co-mid. lat. 45 51		

Then describe the arc EF with the sine of $45^{\circ} 51'$, and therein apply CD from E to F; through F draw AB; and draw the diff. long. B m.

To find the diff. longitude.			C : T :: P : L.		
As co-f. m. lat. = $44^{\circ} 09'$	0,14417		Now $9^{\circ} 02' W.$	=	Dep long.
To tang. cour. = 33 19	9,81776		60) 786 (13 06 W.	=	Diff. long.
So diff. lat. = 858,2	2,93359		22 08 W.	=	Pref. long.
To diff. long. = 786,2	2,89552		Course is NW. b. N. nearly.		

By the TRAVERSE TABLE.

Now $\frac{1}{20}$ th of the distance is 51,35, and of the departure 28,2.

Find under what course, among the degrees, 28,2 stands in the departure column against 51,35 in the column of distances; which will be under $33^{\circ} 30'$ and against 42,8 in the diff. of lat. column.

Then $42,8 \times 20 = 856$: hence the present latitude is $51^{\circ} 16' N.$; and the co-middle latitude is $45^{\circ} 52'$.

With the nearest co-middle latitude (46°) and the departure 28,2 find 39,2; the diff. longitude, among the distances.

Then $39,2 \times 20 = 784$, for the diff. longitude.

69. By

By MERCATOR'S SAILING.
69. By CONSTRUCTION. Fig. 23. Plate XIII.

Draw a meridian AB; describe a quadrant A m p; make A a = 564; draw a c parallel to AB; from A with 1027, the distance, cut a c in c; draw the departure CD parallel to A p, and draw the distance AC.

COMPUTATION by Meridional Parts.

To find the course.

AC : rad. :: CD : sin. $\angle$ DAC.	
As dist. = 1027	6,98843
To rad. = 90° 00'	10,00000
So depart. = 564	2,75128
To sin. cour. = 33° 19'	9,73971

To find the diff. latitude.

Rad. : AC :: sin. $\angle$ DCA : AD.	
As Rad. = 90° 00'	10,00000
To dist. = 1027	3,01157
So col. cour. = 33° 16'	9,92202
To diff. lat. = 858,2	2,93359

Now 37° 00' N. = Dep. lat	
60) 858 (14 18 N. = Diff. lat	
51 18 N. = Pres. lat	

To 51° 18', the mer. parts = 3598	
To 37 00, the mer. parts = 2394	
Mer. diff. lat. = 1204	

Then make AB = 1204; continue AC till it meets BE, drawn parallel to A p; and BE is the diff. longitude.

To find the diff. longitude.

As rad. = 90° 00'	10,00000
To tang. cour. = 33 19	9,81776
So m. diff. lat. = 1204	3,08063
To diff. long. = 791,4	2,89839

Rad. : T :: M : L.	
Now 9° 02' W. = Long. from,	
60) 791 (13 11 W. = Diff. long.	
22 13 W. = Pres. long.	

Course NW. b. N. nearly.

COMPUTATION by Logarithmic Tangents.

Find the course and present latitude as above.

Then, Dep. lat. 37° 00' N.	Co-lat. 53° 00'.	$\frac{1}{2}$ co-lat. 26° 30'.
Pres. lat. 51 18 N.	Co-lat. 38 42.	$\frac{1}{2}$ co-lat. 19 21.

To $\frac{1}{2}$ co-lat. 26° 30', its log. tang.	=	9,69774
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To $\frac{1}{2}$ co-lat. 19 21, its log. tang,	=	9,54552
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Difference	=	1522,2 = G.
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To find the diff. longitude.

As N =	9,89849
To G = 1522	3,18241
So tang. cour. = 33° 19'	9,81776
To diff. long. = 791,8	2,89866

N : G :: T : L.

The present longitude may be found as above.

By the TRAVERSE TABLE.

Find, as before, by proportioning for the parts, the diff. lat. = 856, and the course N. 33° 30' W.

Hence the present lat. is 51° 16' N.; and the mer. diff. lat. = 1200, 10th of which is 60.

Then in the column of latitudes, under 33° 30', find 60,04, the nearest to 60; against which, in the departure, stands 39,74; which, multiplied by 20, gives 794,8 for the diff. of longitude.

70.

PROBLEM X.

Given one latitude, departure, and diff. longitude:

Required the other latitude, course, and distance.

EXAM. A ship from the latitude $51^{\circ} 18' N.$, longitude $22^{\circ} 06' W.$, having sailed between the S. and E. for several days, reckons she has made 564 miles of departure, and 786 miles of longitude: what is the lat. and long. of the place arrived at, and also her direct course and distance?

This Problem cannot be resolved by Mercator's sailing.

By MIDDLE LATITUDE SAILING.

By CONSTRUCTION. Fig. 16. Plate XIII.

Draw a meridian AD; describe the quadrant A m p; in the arc m p apply the chord m B = 786, the diff. long.; draw AB; make m a = 564; draw a F parallel to A m, and with the radius AF describe the arc FE, and draw the chord EF.

Then is EF the departure, and AE the sine of the co-mid. lat.

By COMPUTATION.

To find the co-mid. latitude.

$L : D :: \text{rad.} : c.$			Now Co-mid. lat. = $45^{\circ} 51'$	
			Middle lat.	44 09
As diff. long.	= 786	7,10458	Sum of the lats.	88 18
To depart.	= 564	2,75128	Depart. lat.	51 18
So rad.	= $90^{\circ} 00'$	10,00000	Pres. lat.	37 00
To co-f. m. lat.	= $44^{\circ} 09'$	9,85586	Diff. lat.	14 18 = 858 m.

Make AD = 858; draw DC parallel to A p, and equal to EF; then AC being drawn, will be the distance; and $\angle DAC$ the course.

To find the course.

To find the distance.

$P : L :: C : T.$			$\text{Sin. } \angle DAC : DC :: \text{rad.} : AC.$	
As diff. lat.	= 858	7,06651	As fin. cour.	= $33^{\circ} 19'$ 0,26022
To diff. long.	= 786	2,89542	To depart.	= 564 2,75128
So co-f. m. lat.	= $45^{\circ} 51'$	9,85583	So rad.	= $90^{\circ} 00'$ 10,00000
To tang. cour.	= 33 19	9,81776	To dist.	= 1027 3,01150

Now $22^{\circ} 06' W.$ = Dep. long.

60) 786 (13 06 E. = Diff. long.

9 00 W. = Pres. long.

The course is SE, b. S. nearly.

Distance 1027 miles.

Present lat. $37^{\circ} 00' N.$

By the TRAVERSE TABLE.

Now $\frac{1}{20}$ th of the diff. long. and dep. are 39,3 and 28,2.

Seek in the table, until the given depart. 28,2 is found in its column against the given diff. long. 39,3 in the column of distance; and it gives the co-mid. lat. among the degrees at the top or bottom of the table.

Here 28,2 falls between 28,27 (over 46°) and 28,11 (over $45^{\circ} 40'$) the depart. answering to the dist. 39,3; therefore, taking the co-mid. lat. = $45^{\circ} 50'$, the present lat. is $37^{\circ} 02' N.$; the diff. lat. is 856; and its $\frac{1}{20}$ th is 42,8.

Then 42,8 and 28,2 will be found together under $33^{\circ} 30'$, the course, and between 51 and 52 in the distances; suppose 51,2, which, multiplied by 20, gives 1024 for the distance.

PROBLEM

PROBLEM XI.

71. Given one latitude, course, and difference of longitude :
Required the other latitude and distance.

EXAM. A ship from the lat. $37^{\circ} 00' N.$, longitude $22^{\circ} 56' W.$, runs on a course $N.$, $33^{\circ} 19' E.$, until she finds her difference of longitude is 786 miles: what is her present latitude and distance sailed?

This problem cannot be resolved by middle latitude sailing.

By MERCATOR'S SAILING.

By CONSTRUCTION. Fig. 24. Plate XIII.

Draw the meridian AB ; describe the quadrant Amp ; continue Ap till $Aa=786$ miles, the diff. longitude, and draw AE parallel to AB . Make the arc $mc=33^{\circ} 19'$; draw the rhumb Ac till it meets AE in e , and draw EB parallel to Ap .

COMPUTATION by Meridional Parts.

To find the mer. diff. latitude.

T : R :: L : M.	Dep. lat. $37^{\circ} 00' N.$	Mer. pts. 2393
As tang. cour. = $33^{\circ} 19'$		Mer. d. lat. 1196
To rad. = $90^{\circ} 00'$		
So diff. long. = 786		
	2,89542	Pres. lat. $51^{\circ} 12\frac{1}{2}' N.$
		M. pts. 3589
To m. diff. lat. = 1196	3,07766	Diff. lat. $14^{\circ} 12\frac{1}{2}' = 852\frac{1}{2}$ miles.

Make $AD=852\frac{1}{2}$; draw DC parallel to Ap ; then AC is the distance.

To find the distance. $\sin. \angle DCA$; $AD :: \text{rad.} : AC.$

As cof. cour. = $33^{\circ} 19'$	0,07798
To diff. lat. = $852,5$	2,93069
So rad. = $90^{\circ} 00'$	10,00000
To distance = 1020	3,00867

COMPUTATION by Logarithmic Tangents.

To find the present latitude.

T : L :: N : G.	Dep. lat. $37^{\circ} 00'$	Co-lat. $53^{\circ} 00'$
As tang. cour. = $33^{\circ} 19'$		$\frac{1}{2}$ co-lat. 26 30.
To diff. long. = 786		L. tang. 9,69774
So N =	10,10151	G = 1511
To G = 1511	3,17917	$\frac{1}{2}$ co-lat. 19 24.
		L. tang. 9,54664
		Co-lat. 38 48

Therefore the pres. lat. is $51^{\circ} 12' N.$

By the TRAVERSE TABLE.

Seek the diff. long. in the column of departure to the given course, and it gives in the column of latitude the meridional diff. lat.

Thus under $33^{\circ} 15'$, against 39,3 ($=\frac{1}{20}$ th of 786) in the departure stands 59,38; or by proportioning 59,96, which, multiplied by 20, gives 1199 for the mer. diff. lat. Hence the present lat. is $51^{\circ} 14' N.$; and the diff. lat. 854; its $\frac{1}{20}$ th is 42,7.

Then under $33^{\circ} 15'$, in the col. of lat. 42,7 stands against 51 in the col. of distances; which multiplied by 20, gives 1020 for the distance.

PROBLEM

PROBLEM XII.

72. Given the course, departure, and difference of longitude :
Required the latitudes, departed from and arrived at.

EXAM. From a place in north latitude, a ship sails S. $33^{\circ} 15'$ E. until she has made 564 miles of departure, and 786 miles of difference of longitude : what were the latitudes sailed from and arrived in ?

SOLUTION.

As the sine of the course is to the departure
So is the co-sine of the course to the difference of the latitude = 860
And as the diff. longitude is to the departure
So is the radius to the co-sine of the middle latitude = 44,09.

Now $\frac{860}{60} = 14^{\circ} 20'$ the diff. lat. the half is $7^{\circ} 10'$.

Then $44^{\circ} 09' + 7^{\circ} 10' = 51^{\circ} 19'$, the latitude sailed from ;

And $44^{\circ} 09' - 7^{\circ} 10' = 36^{\circ} 59'$, the latitude arrived in.

Hence any two of these four particulars being given, viz.
Course, distance, departure, difference of latitude,
together with the difference of longitude :
The two latitudes may thence be found.

PROBLEM XIII.

73. Given one latitude, distance, and difference of longitude :
Required the course, and the present latitude.

SOLUTION.

1. Find the meridional distance (37) to use as a first departure.
When the course is toward the equator, augment this mer. dist. for a second departure ; if toward the pole, diminish it for a second departure. Let the 1st dep. be altered about a 5th or 6th of itself for a second departure.
2. With the given distance and these departures, taken separately in order ; Find the respective courses, and differences of latitudes. (VII. 32)
And hence, the present latitudes and mer. differences of lat. (52)
3. To each course and respective mer. diff. lat. find a diff. long. (48)
4. Between each of these differences of longitude, taken in order, and that given, take the two differences ; which call the 1st and 2d errors.
Take the product of the 1st departure by the 2d error, and the product of the 2d departure by the first error.

5. If the two differences of longitude found by the 3d art. were both too great, or both too small; let the difference of the said two products be divided by the difference of the errors, and the quotient may be taken for the true departure.

But if the two differences found were one too great, and one too small; let the sum of the said products be divided by the sum of the said errors, and the quotient may be taken for the true departure.

6. With the true dep. and dist. find the true course and diff. latitude.

(VII. 32)

EXAM. A ship from the latitude of 37° N., having sailed for some days on a direct course in the NW. quarter, finds that she has run 1027 miles, and has made 790 miles of difference of longitude: on what course did she steer, and what latitude has she come to?

With radius and the diff. long. 790, find a mer. dist. (631) which being diminished by about its $\frac{1}{4}$ th, or by 100, gives 531.

Then 631 and 531 may be taken for the 1st and 2d departures.

The distance 1027, and these departures, give the courses $37^{\circ} 45'$ and 31° , and also the differences of latitude 814 and 883; or $13^{\circ} 34'$ and $14^{\circ} 43'$.

Hence the supposed latitudes are $50^{\circ} 34'$ and $51^{\circ} 43'$; and the meridional differences of latitude will be 1135 and 1245.

With 1135 and 1245, taken with the courses $37^{\circ} 45'$ and 31° , the differences of long. are 879 and 748.

And $879 - 790 = 89$, the 1st error, too great:

Also $790 - 748 = 42$, the 2d error, too small.

The sum of these errors is 131, the divisor.

Now $631 \times 42 = 26502$; and $531 \times 89 = 47259$; the sum of these products is 73761.

Then $73761 \div 131$ gives 563 for the true departure.

With the dist. 1027 and dep. 563, the course is N. $33^{\circ} 15' W$.

The diff. lat. is 860 m. $= 14^{\circ} 20' N$.

And the present latitude is $51^{\circ} 20' N$.

SECTION V.

Of compound Courses corrected by Longitude.

How to solve compound courses or traverses, on the principles of plane sailing, has been already shewn; but it is necessary also to shew how the proper allowances for longitude are to be introduced into such accounts; which is easily done by any of the following methods.

74.

RULE I.

1st. Complete the traverse table to each course and distance, and find the whole diff. latitude, departure, and present latitude. (VII. 36)

2d. With the diff. latitude and departure find the direct course and distance. (VII. 33)

3d. If you work by middle latitude, with the departed latitude and present latitude find the co-mid. lat.; with which, and the departure, find the difference of longitude. (64)

Or 4th. If by Mercator, with the departed latitude and present latitude find the meridional difference of latitude; with which, and the direct course, find the difference of longitude. (59)

75.

RULE II. *By Middle Latitude.*

1st. To the traverse table (completed as above) annex seven other cols.; intitle them dep. lats., pres. lats., sum. lats., mid. lats., co-mid. lats., diff. longit.

E. | W.

2d. By the several differences of latitude found in the traverse table, fill up the first and second columns; and hence the corresponding sum. lats., mid. lats., and co-mid. lats., will be obtained.

3d. With each co-mid. lat., and corresponding departure, find the diff. of longitude to each course (64), and set them in the columns marked E. W., according to the name of the departure used.

4th. Add up both the east and west columns of longitude, and the difference of their sums will be the whole difference of longitude.

76.

RULE III. *By Mercator.*

1st. To the traverse table (completed as above) annex five other columns: intitle them successive latitudes, meridional parts, mer. diff. lat., diff. long.

E. | W.

2d. By the several differences of latitude, found in the traverse table, fill up the column of successive latitudes; set their meridional parts in its column; and the meridional differences in its column.

3d. To each course, and its corresponding meridional diff. lat., find (59) the diff. longitude; which set in its proper column.

4th. The difference of the sums of the east and west columns of longitude will be the whole difference of longitude.

The first of these rules is most commonly practised at sea; but either of the latter gives the result more accurately.

The operations, by these rules, may be all performed by the traverse table at the end of Book VII,

77. EXAM.

77. EXAMPLE I. Yesterday noon we were in latitude $38^{\circ} 14' N.$, longitude $25^{\circ} 56' W.$, and have since run the following courses and distances.

1st. NE. b. N. $\frac{1}{4} E.$ 56 m.; 2d. NNW. 38 m.; 3d. NW. b. W. 46 m.;

4th. SSE. 30 m. 5th. S. b. W. 20 m.; 6th. NE. b. N. 60 m.

Required the ship's place with her direct course and distance.

By the FIRST RULE.

The TRAVERSE TABLE.					
Courses.	D.	N.	S.	E.	W.
NE. b. N. $\frac{1}{4} E.$	56	45,0		33,4	
NNW.	38	35,1			14,5
NW. b. W.	46	25,6			38,2
SSE.	30		27,7	11,5	
S. b. W.	20		19,6		3,9
NE. b. N.	60	50,0		33,3	
		155,7	47,3	78,2	56,6
Diff. lat.		108,4	Dep.	21,6	

Hence (VII. 33) the course is N. b. E., distance 111 miles.

By MIDDLE LATITUDE.

Dep. lat. = $38^{\circ} 14' N.$

Diff. lat. = $1^{\circ} 48' N.$

Present lat. = $40^{\circ} 2' N.$

Sum. lats. = $78^{\circ} 16'$

Mid. lat. = $39^{\circ} 8'$

Co-mid. lat. = $50^{\circ} 52'$

Dep. long. = $25^{\circ} 56' W.$

Diff. long. = $0^{\circ} 28' E.$ (64)

Long. from = $25^{\circ} 56' W.$

Present long. = $25^{\circ} 28' W.$

By MERCATOR.

Dep. lat. $38^{\circ} 14' N.$ M. pts. = 2486,1 Depart. long. = $25^{\circ} 56' W.$

Pres. lat. $49^{\circ} 2' N.$ M. pts. = 2625,3 Diff. long. = $0^{\circ} 28' E.$ (59)

Mer. diff. lat. = 139,2 Present long. = $25^{\circ} 28' W.$

EXPLANATION.

The diff. lat. 108,4 and the dep. 21,6 being sought for, standing together in the traverse table (VII. 67) will be found under one point, or $11^{\circ} 15'$ for the course, and against 111 miles for the distance.

The co-mid. lat. $50^{\circ} 52'$, or its nearest $50^{\circ} 45'$, being found in the traverse table (VII. 67), and the departure 21,6 in the dep. column; then right against it in the col. of dist. stands 28 for the diff. long.

The course $11^{\circ} 15'$ being found among the deg. at top in the traverse table (VII. 67), and the mer. diff. lat. 139,2 (or its $\frac{1}{2}$, viz. 69,6) found in the col. of lat., gives a corresponding dep. 28, ($= 13,85 \times 2$) for the difference of longitude.

By

By the SECOND RULE.

TRAVERSE TABLE.						LONGITUDE TABLE.						Diff. lat.
Courses.	D.	N.	S.	E.	W.	Dep. lats.	Pref. lats.	Sum. lats.	Mid. lats.	C. M. lats.	E. W.	
NE.b.N. $\frac{1}{4}$ E.	56	45,0		33,4		38° 14'	38° 59'	77° 13'	38° 36'	51° 24'	43	
NNW.	38	35,1			14,5	38 59	39 34	78 33	39 16	50 44	19	
NW.b. W.	46	25,6			38,2	39 34	40 0	79 34	39 47	50 13	50	
SSE.	30		27,7	11,5		40 0	39 32	79 32	39 46	50 14	15	
S. b. W.	20		19,6		3,9	39 32	39 12	78 44	39 22	50 38	5	
NE. b. N.	60	50,0		33,3		39 12	40 2	79 14	39 37	50 23	43	
		155,7	47,3	78,2	56,6						101	
Diff. lat. =		108,4	Dep.	21,6						Diff. longitude. =	27	

EXPLANATION.

Dep. lat. 38° 14' N., and diff. lat. 45' N., gives pref. lat. 38° 59' N.

Dep. lat. 38 59 N., and diff. lat. 35 N., gives pref. lat. 39 34 N.

Dep. lat. 39 24 N., and diff. lat. 26 N., gives pref. lat. 40 0 N.

Dep. lat. 40 0 N., and diff. lat. 28 S., gives pref. lat. 39 32 N.

And so on, to make the first two columns in the longitude table.

The sum of each opposite two gives the sum of lats. in 3d column.

From these arise the columns of mid. lat. and co-mid. lat.

Then (by art. 64) with each co-mid. lat., and corresponding departure, the column of longitude is filled up; and the sums of the columns of longitude being taken, their diff. will be the whole diff. of longitude.

By the THIRD RULE.

TRAVERSE TABLE.						LONGITUDE TABLE.				
Courses.	D.	Diff. lat.		Depart.		Success. latits.	Mer. parts.	M. Diff. lat.	Diff. long.	
		N.	S.	E.	W.					W.
NE.b.N. $\frac{1}{4}$ E.	56	45,0		33,4		38° 14'	2486,1			
NNW.	38	35,1			14,5	38 59	2543,7	57,6	43,8	
NW. b. W.	46	25,6			38,2	39 34	2588,9	45,2		18,7
SSE.	30		27,7	11,5		40 0	2622,7	33,8		50,5
S. b. W.	20		19,6		3,9	39 32	2586,3	36,4	15,0	
NE. b. N.	60	50,0		33,3		39 12	2560,4	25,9		5,1
						40 2	2625,3	65,9	43,3	
		155,7	47,3	78,2	56,6				102,1	74,3
Diff. lat. =		108,4	Dep.	21,6					Diff. longit. =	27,8

EXPLANATION.

The column of successive lats. is filled up from the differences of lat. found in the traverse table: to these lats. the meridional parts and the differences are to be found: then by the courses and meridional diff. of latitudes, the diff. of longitudes are found, as shewn in art. 59 of this book. The diff. of long. made good, found by all the methods, is nearly the same.

78. EXAMPLE II. Suppose a ship from the latitude $52^{\circ} 20' N.$, and longitude $14^{\circ} 38' W.$, has sailed the following courses, viz.

1st. ESE. 43m. 2d. SW. 32m. 3d. SE. b. S. 58 m.
4th. SSW. 60m.

Required her present latitude and longitude, also her direct course and distance.

By the FIRST RULE.

The TRAVERSE TABLE.					
Courses.	D.	N.	S.	E.	W.
ESE.	43		16,5	39,7	
SW.	32		22,6		22,6
SE. b. S.	58		48,2	32,2	
SSW.	60		55,4		23,0
Diff. lat. =		142,7	71,9	45,6	
Departure =			26,3		

Hence (VII. 33) the course is S. $10^{\circ} 30'$ E. distance 146 miles.

To find the difference of Longitude.

By MIDDLE LATITUDE.

Dep. lat.	=	$52^{\circ} 20' N.$	Mid. lat.	=	$51^{\circ} 8'$
Diff. lat.	=	2 23 S.	Co-mid. lat.	=	$38^{\circ} 52'$
Present lat.	=	49 57 N.	Dep. long.	=	$14^{\circ} 38' W.$
Sum. lats.	=	102 17	Diff. long.	=	$0^{\circ} 42' E.$ (64)
			Present long.	=	$13^{\circ} 56' W.$ (VI. 53)

By MERCATOR.

Dep. lat. $52^{\circ} 20' N.$ Mer. parts	3698	Depart. long.	=	$14^{\circ} 38' W.$
Pres. lat. 49 57 N. Mer. parts	3470	Diff. long.	=	$0^{\circ} 42' E.$ (59)
Mer. diff. lat.	228	Present long.	=	$13^{\circ} 56' W.$ (VI. 53)

EXPLANATION.

The halves of the diff. lat. and dep., viz. 71, 35, and 13,15, being sought for, standing together, in the traverse table (VII. 67), their nearest numbers, viz. 71,73 and 13,30, stand under $10^{\circ} 30'$ for the course; and against 73 in the column of dist.; which doubled, as the table was entered with halves, gives 146 for the direct distance made good.

The co-mid. lat. $38^{\circ} 52'$, or its nearest $38^{\circ} 45'$, being sought in the traverse table (VII. 67); then in the column signed Dep. the number nearest to 26,3 (the dep. by this question) stands against 42 in the col. of dist.; which is to be taken for the difference of longitude.

Or thus, Seek under the direct course $10^{\circ} 30'$, and in the column signed Lat. for the nearest number to the mer. diff. lat. (=228, or to some part thereof, viz. its $\frac{1}{4}$ =) 57; then the corresponding departure is 10,57; which, taken four times, gives 42,28 for the difference of longitude.

By the SECOND RULE.

TRAVERSE TABLE.						LONGITUDE TABLE.						
Courses.	D.	N.	S.	E.	W.	Dep. lats.	Pref. lats.	Sum lats.	Mid. lats.	Co-m. lats.	D lon.	
											E.	W.
ESE.	43		16,5	39,7		52° 20'	52° 04'	104° 24'	52° 12'	37° 48'	65	
SW.	32		22,6		22,6	52 04	51 41	103 45	51 52	38 08		37
SE. b. S.	58		48,2	32,2		51 41	50 53	102 34	51 17	38 43	51	
SSW.	60		55,4		23,0	50 53	49 58	100 51	50 26	39 34		36
Diff. lat. =			142,7	71,9	45,6						116	73
Depart. =				26,3							Diff. lon. = 43	

EXPLANATION.

Dep. lat. 52° 20' N., and diff. lat. 16 S., give pref. lat. 52° 04' N.

Dep. lat. 52 04 N., and diff. lat. 23 S., give pref. lat. 51 41 N.

Dep. lat. 51 41 N., and diff. lat. 48 S., give pref. lat. 50 53 N.

Dep. lat. 50 53 N., and diff. lat. 55 S., give pref. lat. 49 58 N.

Which completes the first two columns of the longitude table.

The sums of the opposite dep. lat. and pref. lat. make the 3d column.

The halves of these sums make the mid. lats. in the 4th column.

And their complements make the 5th column.

Then with these co-mid. lats. and their corresponding departures, the differences of longitude being found (64), and set in their proper columns; the difference of the sums of the columns of longitude gives the whole difference of longitude.

By the THIRD RULE.

TRAVERSE TABLE.						LONGITUDE TABLE.				
Courses.	D.	N.	S.	E.	W.	Success. lats.	Merid. parts.	Mid. lat.	Diff. long.	
									E.	W.
ESE.	43		16,5	39,7		52° 20'	3697,8			
SW.	32		22,6		22,6	52 04	3671,7	26,1	62,8	
SE b. S.	58		48,2	32,2		51 41	3634,4	37,3		37,3
SSW.	60		55,4		23,0	50 53	3557,7	76,7	51,2	
						49 58	3471,4	86,3		35,7
Diff. lat. =			142,7	71,9	45,6				114,0	73,0
Depart. =				26,3		Diff. long. =			41,0	

EXPLANATION.

By the differences of latitude, first found, the column of successive latitudes is filled up; to these the meridional parts and their differences are then taken; the courses and corresponding meridional diff. lat. give (59) the differences of longitude.

In this example, the difference in the result by the three methods is very inconsiderable.

79. EXAMPLE III. Suppose a ship from the latitude $67^{\circ} 30' N.$, longitude $8^{\circ} 46' W.$, has sailed the following courses, viz.

NE. 64 m. NNE. 50 m. NW. b. N. 58 m. WNW. 72 m.
West, 48 m. SSW. 38 m. S. b. E. 45 m. ESE. 40 m.
Required her present latitude and longitude.

By MIDDLE LATITUDE, according to the second Rule.

Courses.	D.	Diff. lats.		Depart.		Success. lats.	Sum lats.	Mid. lats.	Co-m. lats.	D.long.	
		N.	S.	E.	W.					E.	W.
NE.	64	45,3		45,3		67° 30'	0	0	0		
NNE.	50	46,2		19,1		68 15	135 45	67 52	22 08	120	
NW.b.N.	58	48,2			32,2	69 01	137 16	68 38	21 22	53	
WNW.	72	27,6			66,5	69 49	138 50	69 25	20 35		92
West	48				48,0	70 17	140 06	70 03	19 57		195
SSW.	38		35,1		14,5	70 17	140 34	70 17	19 43		142
S. b. E.	45		44,1	8,8		69 42	139 59	69 59	20 01		42
ESE.	40		15,3	36,9		68 58	138 40	69 25	20 40	25	
						68 43	137 41	68 50	21 10	102	
		167,3	94,5	110,1	161,2					300	471
Diff. lat.= 72,8		Depart. = 51,1				Diff. long. = 171					

By MERCATOR, according to the third Rule.

Courses.	D.	Diff. lat.		Depart.		Success. lats.	Mer. parts.	Mer. d. lat.	Diff. long.	
		N.	S.	E.	W.				E.	W.
NE.	64	45,3		45,3		$67^{\circ} 30'$	5551,6			
NNE.	50	46,2		19,1		68 15	5671,1	119,5	119,5	
NW. b. N.	58	48,2			32,2	69 01	5797,3	126,2	52,4	
WNW.	72	27,6			66,5	69 49	5933,9	136,6		91,1
West	48				48,0	70 17	6016,0	82,1		198,6
SSW.	38		35,1		14,5	70 17	6016,0	00,0		142,*
S. b. E.	45		44,1	8,8		69 42	5913,7	102,3		42,4
ESE.	40		15,3	36,0		68 58	5789,0	124,7	24,8	
						68 43	5747,4	41,6	100,7	
		167,3	94,5	110,1	161,2				297,4	474,1
Diff. lat. = 72,8 Depart. = 51,1 Diff. longit. = 176,7										

Hence the present latitude is $68^{\circ} 43' N.$; and present long. $11^{\circ} 42' W.$

According to the first Rule.

The co-mid. lat. between the first and last lats. is $21^{\circ} 54'$, with which, and the departure 51,1, the diff. long. will be 137 miles.

Also the mer. diff. lat. between the first and last lats. is 195,8; with which, and the diff. lat. 72,8, and the dep. 51,1, gives a diff. long. 137,1.

* This diff. long. is found by Art. 38 of this Book.

80. EXAMPLE IV. Suppose a ship from the latitude $68^{\circ} 38' N.$ longitude $8^{\circ} 40' E.$ has sailed the following courses, viz.

NE. b. N. 63m.	NE. 38m.	NNE. 56m.
North 30m.	NW. b. N. 25m.	NNW. $\frac{1}{2}$ W. 36m.
N. by E. 40m.	NE. b. E. $\frac{1}{2}$ E. 72m.	SE. 50m.
ENE. 65m.		

Required her present latitude and longitude, with her direct course and distance to the North Cape, in lat. $71^{\circ} 27' N.$, longitude $26^{\circ} 30' E.$

By MIDDLE LATITUDE, according to the second Rule.

Courses.	D.	Diff. lats.		Depart.		Success. lats.	Sum lats.	Mid. lats.	Co-m. lats.	D. lon.	
		N.	S.	E.	W.					E.	W.
NE. b. N.	63	52,4		35,0		$68^{\circ} 38'$					
NE.	38	26,9		26,9		69 30	138 8	69 4	20 56	98	
NNE.	56	51,7		21,4		69 57	139 27	69 43	20 17	78	
North.	30	30,0				70 49	140 46	70 23	19 37	64	
NW. b. N.	25	20,7			13,9	71 19	142 8	71 4	18 56	00	00
NNW. $\frac{1}{2}$ W.	36	31,7			17,0	71 40	142 59	71 30	18 30		44
N. b. E.	40	39,2		7,8		72 12	143 52	71 56	18 4		55
NE. b. E. $\frac{1}{2}$ E.	72	33,9		63,5		72 51	145 3	72 31	17 29	26	
SE.	50		35,3	35,3		73 25	146 16	73 8	16 52	220	
ENE.	65	24,9		60,0		72 50	146 15	73 7	16 53	121	
						73 15	146 57	73 31	16 57	205	
		311,4	35,3	249,9	30,9					812	99
Diff. lat. =		276,1		219,0	Dep.					Diff. long. =	713

By MERCATOR, according to the third Rule.

Courses.	D.	Diff. lats.		Depart.		Success. lats.	Mer. parts.	Mer. d-lat.	Diff. long.	
		N.	S.	E.	W.				E.	W.
NE. b. N.	63	52,4		35,0		$68^{\circ} 38'$	5733,7			
NE.	38	26,9		26,9		69 30	5879,2	145,5	97,2	
NNE.	56	51,7		21,4		69 57	5957,2	78,0	78,0	
North	30	30,0				70 49	6112,1	154,9	64,0	
NW. b. N.	25	20,7			13,9	71 19	6204,5	92,4		
NNW. $\frac{1}{2}$ W.	36	31,7			17,0	71 40	6270,7	66,2		44,0
N. b. E.	40	39,2		7,8		72 12	6373,9	103,2		55,0
NE. b. E. $\frac{1}{2}$ E.	72	33,9		63,5		72 51	6503,8	129,9	26,0	
SE.	50		35,3	35,3		73 25	6621,0	117,2	219,4	
ENE.	65	24,9		60,0		72 50	6500,4	120,6	120,6	
						73 15	6586,1	85,7	207,0	
		311,4	35,3	249,9	30,9				812,2	99,0
		35,3		30,9					99,0	
Dep. lat. =		276,1		219,0	Dep.				Diff. long. =	713,2

By

By the FIRST RULE.

With $\frac{1}{10}$ th of the diff. lat. and departure, viz. 27,61 and 21,9, the direct course is N. $38^{\circ} 30'$ E., and distance 353.

The co-mid. lat. is $19^{\circ} 04'$; with which, and the departure 219, the difference of longitude is 673.

The meridional diff. lat. 852,4; with which, and the direct course $38^{\circ} 30'$, the difference of longitude is 676.

To find the direct course and distance from the ship's place to the North Cape.

Depart. lat.	= $68^{\circ} 38' N.$	Dep. long.	= $8^{\circ} 40' E.$
Diff. lat.	= $4 36 N.$	Diff. long.	= $11 53 E.$
Present lat.	= $73 14 N.$	Present long.	= $20 33 E.$
N. Cape's lat.	= $71 27 N.$	N. C.'s long.	= $26 30 E.$
	Mer. parts = 6582,6		
	Mer. parts = 6229,6		
Diff. lat.	= $1 47 N$	M. d. lat.	= $353,0$
		Diff. long.	= $5 57 E.$
Or	= 107 miles.	Or	= 357 miles.

By MIDDLE LATITUDE.

Sum of the lats. $144^{\circ} 41'$; mid. lat. $72^{\circ} 21'$; co-mid. lat. $17^{\circ} 39'$.

To the co-mid. lat. $17^{\circ} 39'$, and the diff. longitude 357 ($= 119 \times 3$) taken as a distance, the corresponding depart. is ($36,28 \times 3 =$) 108,84.

As the diff. lat. 107, and depart. 108,8, are so nearly equal, therefore The course to the North Cape is SE., and the distance 152 miles.

By MERCATOR.

The meridional diff. lat. 353, and diff. long. 357, taken as a diff. lat. and depart. gives the course S. $45^{\circ} 20'$ E. and the distance 152 miles.

81.

REMARK.

The three methods of operation are sufficiently illustrated in the preceding examples. From whence it may be inferred, that in latitudes not exceeding 45° , the *first method*, or that usually practised at sea, is correct enough for any runs that can be made in one or two days; and one day's run may be safely worked by the same method in latitudes as high as 50° or 52° : but in latitudes nearer the pole, it will be proper to find the difference of longitude to compound courses by either of the second or third methods, as may be seen by comparing the results to the third and fourth examples; the first method giving the difference of longitude too small, by a quantity considerable enough to produce fatal consequences.

SECTION VI.

The Construction and Use of a Mercator's Chart.

The linear and numeral solutions of such questions as may be proposed concerning sailing, by the principles on which Mercator's charts are founded, having been sufficiently exemplified; it follows next to shew how such questions may be solved by the chart itself.

82.

PROBLEM I.

To make a true sea-chart, which shall shew the known sea coasts, islands, rocks, shoals, &c. that are contained within any proposed limits.

SOLUTION.

1st. Construct the boundaries or limits of the chart, within the proposed latitudes and longitudes (13), and let the degrees of latitude and longitude be marked on these limits.

2d. On a piece of stiff paper, parchment, &c. make a scale of equal parts, like the degrees of longitude that are in the graduated parallel of latitude, and let the divisions on this scale be numbered in the same manner.

3d. From a table of the latitudes and longitudes of places (VI. 137) extract those places, with their latitudes and longitudes, that lie within the proposed limits.

4th. Then by sliding the outside divisions of the scale of the graduated parallel along the graduated meridians, so that both ends of the scale, at the same time, always cut like divisions of latitude; the points corresponding to the latitudes and longitudes of the places contained within the proposed limits may be readily marked in the chart.

5th. Lines being properly drawn from point to point, will form the outlines of the sea coasts, islands, &c.; to which may be annexed the depths of water, setting of currents, and whatever else may be judged convenient for the chart to contain.

In this manner the sea-coasts, &c. were laid down in the chart, Plate XII.; containing part of the sea coasts of Europe, Africa, and America, with the intermediate islands, extending from the latitude of 23 degrees to 59 degrees north; and from the longitude of London, or 0 degrees, to 80 degrees of west longitude.

83. The Gunter's scales have two lines drawn on them; one marked *M. R.*, signifying the *nautical meridian*; and the other, which is placed directly under it, is marked *E. P.*, signifying *equal parts*.

These equal parts are degrees of longitude, to which the divisions of the nautical meridian are fitted, by increasing them in their true proportion; which is readily done by the table in Art. 13, taking the meridional degrees from the scale of equal parts, or degrees of longitude. These two lines, or scales, are used either to construct a Mercator's chart, or to shew nearly the meridional diff. lat. between any two parallels of latitude.

The

The construction of a Mercator's chart (or rather the limits or borders of it) is easily performed by these lines, by transferring the divisions, corresponding to the degrees to be used, from these scales to the paper the chart is to be drawn on. See Plate XII. Thus :

On an east and west line (AB) apply the extent, taken from the scale of longitude (EP), between the degrees of longitude where the chart is to begin and end (suppose between the longitudes 0° and 80°).

Through these two extremities (A, B,) draw two meridians (AD, BC,) each of a length equal to the extent, taken from the line of latitudes (Mer.), between the two latitudes where the chart is to begin and end (suppose between the latitudes 23° and 59°).

Then the several degrees both of longitude and latitude, taken from those scales, and separately applied in their respective places, will form the borders of the chart as required.

The meridional difference of latitude is found by taking the extent, on the meridian scale, between the two proposed latitudes, in a pair of compasses, and applying it to the line of longitude; then the number of equatorial degrees, and parts of degrees, being reduced to miles, will shew the meridional diff. latitude between those parallels.

The scale of longitude, which was put perhaps on all the two-feet Gunter's scales made before the year 1746 for common sale, had each degree of longitude rather less than $\frac{1}{8}$ th of an inch, and the meridian scale fitted to that size; so that about 85 meridian degrees came within the length of the scale: and consequently the charts constructed from them had their degrees rather too small to be of much use to seamen, whose instruments and hands are not, usually, so nice as to work with tolerable accuracy on such small charts; and such scales continue still to be made by some workmen. But since that time certain alterations, conceived to be useful, have been made in Gunter's scales by some of the instrument-makers, to whom they were communicated*; and now a degree of longitude is made nearly half an inch, and is divided into five parts of 12 minutes each; and the meridional degrees, fitted thereto, are in two lengths, or scales; the first containing 40 degrees: and the other, beginning at 40° , extends to 68° ; most navigations being performed within those limits.

The scale of logarithmic tangents, put on the Gunter's scale, is also a scale of meridional parts, or a scale of the differences of longitude to a course on the fourth rhumb, or to the rhumb making angles of 45 degrees, with the meridians, on a Mercator's chart.

For to the latitudes 0° , 5° , 10° , 15° , 20° , 25° , 30° , &c.; the half complements are 45° , $42\frac{1}{2}^{\circ}$, 40° , $37\frac{1}{2}^{\circ}$, 35° , $32\frac{1}{2}^{\circ}$, 30° , &c. Therefore, if on the scale of log. tang. be set the numbers 5, 10, 15, &c. against the divisions represented by 45° , $42\frac{1}{2}^{\circ}$, 40° , &c., and the intermediate divisions be estimated accordingly; then will those divisions, taken as latitudes, be the log. tang. of their half polar distances, or half co-latitudes; which (23) are analogous to the lengthened degrees on the meridian; and consequently (19) represent the differences of longitude on the rhumb of 45° .

* By the author of these Elements.

A scale of equal parts, or a scale of longitude proper to this scale of meridional parts, may be found by the table, art. 13, p. 137. Thus, take from the scale of log. tang. marked as the scale of mer. parts, as above said, the mer. parts to any proposed latitude; then that distance, being divided into as many equal parts as there are mer. deg. standing against that latitude in the table, will be the scale of equal parts required.

Thus. The first 20° of lat. which is the distance from the tangent of 45° to the tangent of 35° , being divided into 20,4 equal parts, will be the scale of longitude required.

Also, the first 30° of lat. which is the space between 45° and 30° on the log. tangents, gives 31,5 equatorial parts.

And (which is the most accurate among them) the distance between the tangents of 45° and $22\frac{1}{2}^\circ$, answering to the first 45° of latitude, gives 50,5 equal parts, or degrees of the equator.

84.

P R O B L E M II.

A latitude and longitude being given, to find the corresponding place on the chart. Example. Lat. $32^\circ 25'$ N. long. $17^\circ 21'$ W. Plate XII.

S O L U T I O N.

1st. In the graduated meridian * take the distance between the proposed latitude and the nearest parallel of latitude drawn across the chart with a pair of compasses, as between the lat. $32^\circ 25'$, and the parallel of 30° .

2d. With other compasses, take the distance in the graduated parallel † between the proposed longitude and the nearest meridian drawn across the chart, as between the long. $17^\circ 21'$ W. and the meridian passing through 20° of longitude.

3d. Slide the point of one compass along the meridian of 20° , and a point of the other compass along the parallel of 30° , keeping the points of each pair of compasses perpendicular to the line they slide along; then will the meeting of the other points of the compasses shew the place corresponding to the given latitude and longitude; which in this example is the west end of the island of Madeira.

This problem is most readily solved by the means of such a moveable scale of longitude, as is described and used in the foregoing problem.

Or thus. A meridian drawn through the degrees of longitude given, and a parallel of latitude drawn through the given degrees of latitude, their intersection will be the place required.

* The graduated meridian is the scale of latitudes on the right or left hand borders of the chart.

† The graduated parallel is the scale of longitudes on the top or bottom borders of the chart.

85.

PROBLEM III.

A place being given on the chart, to find its latitude and longitude.

Suppose Palma, one of the Canary Isles. Plate XII.

SOLUTION.

1st. With the compasses take the shortest distance between the given place and the nearest parallel of latitude; this distance, applied to the graduated meridian from the said parallel, the same way the place lies, will give the latitude sought. Thus the distance from Palma to the parallel of 30° , applied from 30° southward, gives $28^\circ 35'$ N. for the latitude sought.

2d. In like manner, the shortest distance taken between the given place and the nearest meridian, being applied to the graduated parallel from that meridian, will give the longitude: thus the distance from Palma to the meridian through 20° , applied from 20° eastward, will give $17^\circ 21'$ W. longitude.

86.

PROBLEM IV.

Two places being given on a Mercator's chart, to find their difference of latitude and difference of longitude.

Suppose Cape Finisterre and the island of Porto Sancto. Plate XII.

SOLUTION.

Find the latitude and longitude of each place; then the required differences are readily known.

By Prob. III. {	C. Finisterre's lat.	=	$43^\circ 15'$ N.	Long.	=	$9^\circ 30'$ W.
	Isl. Porto Sancto lat.	=	$33 \quad 15$ N.	Long.	=	$15 \quad 55$ W.
	Diff. lat.	=	$10 \quad 00$	D. long.	=	$6 \quad 25$ W.

87.

PROBLEM V.

To find the bearing, or course, between two given places on a Mercator's chart.

Suppose between Cape Clear and the island St. Michael. Plate XII.

SOLUTION.

Lay the edge of a ruler upon Cape Clear and the middle of the island of St. Michael; and, holding the ruler in this position, take the shortest distance between the edge of the ruler and the center of the nearest compass, or fly in a pair of compasses; slide one point of the compasses along the edge of the ruler, till the other point cuts the border of the fly; and the course will be found to be SW. b. S. $\frac{1}{4}$ W. nearly.

And the like for other places.

PRO-

P R O B L E M VI.

Two places being given on a Mercator's Chart, to find their distance.

88. CASE I. *When the given places are both under the same meridian, or under the equator.*

SOLUTION.

Find the latitude of each place when under the same meridian, or their longitudes if under the equator.

Then the difference of the latitudes is the distance sought; or, the difference of longitudes is the distance sought.

89. CASE II. *When the given places are both under the same parallel of latitude.*

Suppose between Cape Roxant and the island of St. George. Pl. XII.

SOLUTION.

Lay the edge of a ruler over the given places; take half the distance of those places with the compasses; set one point on the division cut by the ruler in the graduated meridian, and apply the other point upward and downward on the same meridian, noting the degrees of latitude the said point falls on: Then the difference of those latitudes will be the distance sought nearly.

Thus, half the distance between Cape Roxant and the island of St. George, will reach from $38^{\circ} 40'$, the division cut by the edge of a ruler laid over those places, to $45^{\circ} 00'$ northward, and to $32^{\circ} 20'$ southward; the difference between these two latitudes is $12^{\circ} 40'$, or 760 miles nearly, for the distance required.

But if the proposed places lie in a parallel of latitude greater than 30 degrees, it will come nearer the truth to work as follows:

Take that meridional degree in which the parallel falls in the compasses; and as many times as this distance is contained in a straight line between the two places, of so many degrees is their distance to be estimated; which is reduced to miles as before.

Thus the distance between the latitudes of $38^{\circ} 00'$ N. and $39^{\circ} 00'$ N. will be contained about $12\frac{2}{3}$ times between Cape Roxant and the island of St. George, or the distance will be $12^{\circ} 40'$, as before.*

A third method, better than either, is as follows: Consider what number of points and parts of a point is contained in the co-latitude of the given places. Extend the compasses from one place to the other, and set this extent from the center of any one of the compasses, or flies, that is drawn on the chart along the rhumb which expresses the number of points and parts contained in the co-latitude. Keeping one foot of the compasses in the point where it falls, shut in the other until it will just

* These operations depend on the following proportion:

As mer. diff. lat. : proper diff. lat. :: diff. long. : departure; which will differ but very little from the meridional distance, unless the places are very far asunder.

touch the meridian that passes through the center of the fly; and this extent being applied to the graduated parallel will give the distance between the two places in degrees, as is plain from the principles of parallel sailing.

90. CASE III. *When the given places differ both in latitude and longitude.*

Suppose the Lizard and the island of Corvo. Plate XII. Fig. 4.

SOLUTION.

Find the latitudes of the two places, and their diff. latitude. Take the diff. lat. in degrees and parts from the equator.

Lay the edge of a ruler over the two places; and slide one point of the compasses along the edge of it, until the other point touches a parallel (without cutting it); then, the other point resting here, take the distance from thence to where the edge of the ruler cuts this parallel, which being measured on the graduated parallel, will give the distance sought in degrees.

Thus the difference of latitude between Corvo and the Lizard is $10^{\circ} 09'$; then $10^{\circ} 09'$ taken from the graduated parallel, and one point of the compasses applied to the edge of a ruler, laid in the direction CL, slide that point along CL till the other point touches the parallel of 50 degrees in E; then the distance DL, measured on the graduated parallel, gives about $20^{\circ} 25' = 1225$ miles, for the distance required.

For, if the difference of latitude DE be taken on a meridian through c, from c to F; and the parallel of latitude FH be drawn, cutting the rhumb line CL in H; then are the triangles LDE, HCF, congruous; and $CH = DL$. (II. 95, 102)

Now it is evident, that the parts of the triangle CFH, CGL, bear the same proportion to one another, as have been shewn in Art. 25 of this, where CF is the proper diff. lat. CG the mer. diff. lat., GL the diff. long. FH the departure, and CH the distance: Consequently the distance DL, found as above, is the true distance sought.

91. PROBLEM VII.

Given the latitude and longitude of the departed place, the course, and the latitude of the present place: Required that place on the chart.

EXAMPLE.

A ship from the island of Flores runs SE. b. S. $\frac{1}{4}$ E. till she finds herself in the latitude $27^{\circ} 29'$ N.; required her present place. Plate XII. Fig. 5.

SOLUTION.

Through the departed place, Flores, draw the given rhumb, viz. SE. b. S. $\frac{1}{4}$ E. and its intersection with the parallel of latitude drawn through the latitude of the present place, viz. $27^{\circ} 29'$, will give the ship's place on the chart; which will be near the island Ferro, or in lat. $27^{\circ} 48'$ N. long. $17^{\circ} 26'$ W.

92. PRO-

92.

PROBLEM VIII.

Given the departed place, and also the course and distance, to find the present place on the chart.

EXAMPLE.

A ship from the island Ferro runs NW. b. N. $\frac{3}{4}$ W. 951 miles; what is the latitude and longitude of the present place? Plate XII. Fig. 5.

SOLUTION.

Lay the edge of a ruler over Ferro in the position of the given course NW. b. N. $\frac{3}{4}$ W.; take the degrees, $15^{\circ} 51'$, in the given distance, 951 miles, from the graduated parallel, and apply this extent from Ferro along the ruler's edge to R; take the nearest distance between R, and a parallel PZ drawn through Ferro, and see how many degrees this extent makes on the graduated parallel, which will be $11^{\circ} 35'$; those degrees counted northward from Ferro will give $39^{\circ} 23'$ N. for the ship's latitude; then the point Q, where a parallel through this latitude intersects the edge of the ruler, still lying in the first position, will be the ship's present place.

93. *If the course is due east or west.*

EXAMPLE.

A ship from Cape Roxant sails due west 760 miles: required her present place. Plate XII.

SOLUTION.

Take half the degrees (*viz.* $6^{\circ} 20'$) in the given distance 760 miles; add them to, and subtract them from, the given lat. $38^{\circ} 42'$, noting the sum $45^{\circ} 02'$, and the remainder $32^{\circ} 22'$: then the extent between those degrees, taken in the graduated meridian, and applied from the given place westward in the parallel, will give the ship's present place; which will be near the island of St. George.

Or thus, if the latitude be above 30 degrees:

Take the length of a degree in the latitude of the given parallel, as much above the parallel as below it; and turn this distance over in that parallel, the same way the course is, as many times as there are degrees in the given distance, and this will give the ship's place.

Thus the length of a degree taken in the latitude $38^{\circ} 42'$, and turned over from Cape Roxant to the west $12\frac{2}{3}$ times, the compasses will fall on the island of St. George.

Or lay the edge of a ruler over the center of a fly, in the direction of that rhumb which makes an angle with the meridian, equal to the co-latitude of the given place. Take the number of degrees in the given distance from the graduated parallel, and slide one foot of the compasses along the edge of the ruler, until the other touches the meridian passing through the fly. Keeping one foot fixed, in this position, by the edge of the ruler, open the other to the center of the fly; then set this extent from the given place along its parallel of latitude, and it will give the present place of the ship.

94. PRO-

PROBLEM IX.

94. *Given the departed place with the difference of latitude and distance: Required the ship's place on the chart.*

EXAMPLE.

A ship from Q sails in the SE. quarter 951 miles, and then finds herself in lat. $27^{\circ} 48' N.$, having altered her latitude $11^{\circ} 35'$: required her present place. Plate XII. Fig. 5.

SOLUTION.

Take the difference of latitude, $11^{\circ} 35'$, from the graduated parallel; lay this extent from Q along the edge of a ruler, lying north and south, to x; turn the edge of the ruler about x, till it lies in an east and west position: from the graduated parallel take $15^{\circ} 51'$, the degrees in 951 miles, the given distance; apply this extent from Q, to cut the edge of the ruler in v: let the points of the compasses rest in Q and v, and apply the edge of the ruler close to those points; then the point P, where the parallel of $27^{\circ} 48'$ is cut by the ruler's edge, is the ship's place required.

PROBLEM X.

95. *Given the departed place with the course and difference of longitude: Required the ship's place on the chart.*

EXAMPLE.

A ship from P sails NW. b. N. $\frac{3}{4}$ W.: required her place when she has altered her longitude $12^{\circ} 53'$. Plate XII. Fig. 5.

SOLUTION.

Take the given difference of longitude $12^{\circ} 53'$ from the graduated parallel; slide one foot of the compasses along the edge of a ruler laid on P, in the position PQ of the given course, until the other foot just touches a meridian PT drawn through P in T; then will the point Q, where the foot rests against the ruler's edge, be the place required.

96. *If the course had been due east or west.*

EXAMPLE.

A ship from Cape Roxant sails due west until she has altered her longitude $16^{\circ} 40'$: required her place on the chart.

SOLUTION.

Take the difference of longitude $16^{\circ} 40'$ from the graduated parallel: then this extent, applied from the given place, Cape Roxant, due west, will give the place required, which is near the island of St. George.

97. PROBLEM XI.

Given the departed place, with the difference of latitude and departure: Required the ship's place on the chart.

EXAMPLE.

A ship from Q, in lat. $39^{\circ} 23' N.$, sails between the south and east till she comes into the lat. $27^{\circ} 48' N.$, having made by account 649 miles of departure: required the ship's present place. Plate XII. Fig. 5.

SOLUTION.

Take the given difference of latitude $11^{\circ} 35'$ from the graduated parallel, and apply this extent from Q, along the edge of a ruler laid in the meridian of Q to x; take $10^{\circ} 49' = 649$ miles, the given departure, from

from the graduated parallel; set one foot on x , and lay this extent eastward to v . so that xv be in a perpendicular position to the ruler's edge: lay the edge of the ruler on the points Q and v , and where it cuts zp , the parallel of the ship's present latitude in p , is the ship's place.

Then the longitude, course, and distance may be found as before. See Articles 85, 87, 90.

98.

PROBLEM XII.

Given the departed place, with the course and departure: Required the ship's place on the chart.

EXAMPLE.

A ship from p , in latitude $27^{\circ} 48' N.$, sails NW.b. N. $\frac{1}{4} W.$, until she has made 649 miles of departure: required her present place; Plate XII. Fig. 5.

SOLUTION.

Lay the edge of a ruler over the given place p , in the position of the given course NW. b. N. $\frac{1}{4} W.$; take from the graduated parallel $10^{\circ} 49' = 649$, the given departure, and slide one foot along the ruler's edge, until the other foot just touches a meridian PT , drawn through p in s ; the distance sp , applied to the graduated parallel, gives the diff. latitude; and consequently the present latitude is known: then where the ruler's edge, lying in the same position, cuts the present parallel of lat. TQ , as in Q , is the place sought.

99.

PROBLEM XIII.

Given the departed place with the distance, and departure: To find the ship's present place on the chart.

EXAMPLE.

A ship from Q , in lat. $39^{\circ} 23' N.$, in sailing between the south and east 951 miles, found she has made 649 miles of departure: Where is the present place of the ship? Plate XII. Fig. 5.

SOLUTION.

From the graduated parallel take $10^{\circ} 49' = 649$ miles, the given departure, and lay this extent from Q to o directly east; with the extent $15^{\circ} 51' = 951$ miles, the given distance, taken from the graduated parallel, one foot being set in Q ; with the other foot cut the edge of a ruler laid on o , as a meridian, in v ; then ov , measured on the graduated parallel, gives the diff. latitude, and consequently the present latitude $27^{\circ} 48'$ will be found: lay a ruler's edge over Q and v , and where it cuts the parallel of $27^{\circ} 48'$, as in p , is the ship's place required.

SECTION VII.

Of sailing on a Great Circle of the Sphere.

100. GREAT CIRCLE SAILING is the art of finding what places a ship must go through, and what courses she must steer, that her track may be in the arc of a great circle (or nearly so) passing through the place sailed from and that bound to.

Although Mercator's sailing resolves truly all the cases incident to a ship's course along the rhumb passing through two places; yet there is no case in which the course performed on the direct rhumb line is the shortest distance between those two places, except when they both lie under the same meridian, or on the equator.

For, on the sphere, the shortest distance between two places is the arc of a great circle intercepted between them (IV. 23); consequently the spiral, or rhumb, passing through those places, is not the shortest distance, except when that rhumb coincides with a great circle, which can only be on a meridian, or on the equator.

It is chiefly on account of the shortest distance that this method of sailing has been proposed; and, for the most part, it is advantageous for a ship to reach her port by the shortest way she can.

As the solutions of the cases in Mercator's sailing were performed by plane triangles; so the cases in great circle sailing, are resolved by the solution of spheric triangles.

A great variety of cases may be proposed in this kind of sailing; but as they serve rather for exercises in the solution of spheric triangles, than for any real use toward the navigating a ship, those which appertain to one Problem only will be here more particularly considered, as they are the most useful cases that usually occur.

101. The angle of position, is an angle which a great circle, passing over two places, makes with the meridian of one of them; and shews the angular position of one place from the other.

PROBLEM.

Given the latitudes and longitudes of two places on the Earth: Required their nearest distance on the surface, together with the angles of position from either place to the other.

This Problem may be branched into six Cases.

102. CASE I. *When the two places lie under the same meridian.*

SOLUTION. Their difference of latitude will give their distance; and the position of one from the other will be directly north or south.

103. CASE

103. CASE II. *When the two places lie under the equator.*

SOLUTION. Their distance is equal to their difference of longitude, and the angle of position is a right angle, or the course from one to the other is due east or west.

104. CASE III. *When both places are in the same parallel of latitude.*

EXAMPLE. *What is the least distance between St. Mary's, in latitude $37^{\circ} 00' N.$, longitude $25^{\circ} 0' W.$, and Cape Henry, in latitude $37^{\circ} 00'$, longitude $76^{\circ} 23' W.$?*

GENERAL CONSTRUCTION. Plate XIII. Fig. 25.

1st. Describe a circle PESQ, representing the meridian of one of the places, suppose of the eastern one, as St. Mary's; draw the line EQ, representing the equator, and at right angles to it draw the line PS, for the axis of the earth, the extremity of which, P, is the north pole, and S is the south pole; and on this circle lay off from P to A the complement of the latitude of (St. Mary's) the eastern place.

2d. On the equator, lay off from Q to c (IV. 70) the difference of longitude between the two places ($51^{\circ} 23'$); and through P, c, s, (II. 72) describe the circle P c s, which will be the meridian of the other place (Cape Henry); on which lay from P to B the co-latitude of this place; which is done by describing the arc Aa about the pole P (IV. 68) at the distance of the co-latitude.

3d. Through the points A, B, D, describe a great circle ABD. (II. 72)

Then A represents one place (St. Mary's), B the other (Cape Henry); PA and PB are their co-latitudes; the angle APB, which is measured by the arc QC (IV. 9), is the diff. long.; the arc AB is the nearest distance of those places; the angle PAB is the angle of position from A to B; and the angle PBA is the angle of position from B to A.

The arc AB may be measured as directed in Art. 70. Book IV.

And the angle PAB, or PBA, as shewn in Art. 72. Book IV.

Now the places having the same latitude, PA is equal to PB, and $\angle PAB = \angle PBA$ (IV. 90). Therefore, if the arc PI be described (IV. 75) making the angle $\angle API = 25^{\circ} 41\frac{1}{2}'$, the half of the difference of longitude; PI will be perpendicular to AB, and bisect it.]

And in the triangle AIP, right-angled at I, there will be given the hypotenuse $AP = 53^{\circ} 00'$; the $\angle API = 25^{\circ} 41\frac{1}{2}'$: to find the leg $AI =$ half the distance sought, and the $\angle PAI =$ the angle of position.

The solution falls under Art. 130, 132. Book IV.

To find the distance.

As radius,	Or, As rad.	=	90° 00'	10,00000
To fin. hyp. PA;	To co-f. lat.	=	37 00	9,90235
So fin. giv. $\angle API$,	So fin. $\frac{1}{2}$ diff. long.	=	25 41 $\frac{1}{2}$	9,63702
To fin. leg AI.	To fin. $\frac{1}{2}$ distance	=	20 15 $\frac{1}{2}$	9,53937

Which doubled, gives 40 31 for the dist. AB.

And this 40° 31' reduced to nautical miles, is 2431, which is 31 miles less than 2462, the distance given by parallel sailing. See Art. 42 of this.

To find the angle of position.

As radius,	Or, As rad.	=	90° 00'	10,000000
To co-f. hypoth. PA;	To fin. lat. *	=	37 00	9,77946
So tang. giv. $\angle API$,	So tang. $\frac{1}{2}$ diff. long.	=	25 41 $\frac{1}{2}$	9,68222
To co-t. $\angle A$.	To co-t. $\angle$ posit.	=	73 51	9,46168

It appears by this, that to sail from A to B, or from B to A, the ship must first steer N. 73° 51' W. or E.; and then gradually increase her course till she comes to I, where it will be due W. or E.; and from thence the course is to be gradually diminished again till she comes to the other port, where it will be 73° 51', the same as she set out with: But how these courses are to be thus altered will be shewn hereafter.

105. CASE IV. *When one place has latitude, and the other has none, or is under the equator.*

EXAMPLE. *What is the nearest distance between the Island of St. Thomas in lat. 0° 00', and long. 1° 00' E., and Port St. Julian, in lat. 48° 51' S. and longitude 65° 10' W.?*

Port St. Julian, in lat.	48° 51' S.	Long. 65° 10' W.
Isl. St. Thomas, in lat.	0 00	Long. 1 00 E.
Julian's co-lat.	41 09	Diff. long. 66 10

By CONSTRUCTION. Plate XIII. Fig. 26.

Let the point A be St. Thomas under the equator, the poles of which are P and S.

Make AC, the measure of the angle ASC, equal to 66° 10' = diff. long. (IV. 74)

Then as Port St. Julian is in south lat., about S the south pole, at the distance of Julian's co-lat., describe the arc aa, cutting scp, the meridian of Julian, in B. (IV. 66.)

Through the points A, B, E, a great circle being described the arc AB is the distance sought.

The distance AB may be measured by Art. 70. Book IV.

And the angles of position at A and B are to be measured as directed in Art. 72. Book IV.

* For the complement of a complement is the arc itself: Thus QA, or the distance from the equator, shews the lat. But QA is the comp. of AP; and AP of AQ.

COMPUTATION. In the quadrantal triangle ASB, there is
 Given the co-lat. of St. Thomas, or $AS = 90^\circ 00'$ } The rest are found
 the co-lat. of Julian, $SB = 41^\circ 09'$ } as in Art. 162, Book
 the diff. longitude, $\angle ASB = 66^\circ 10'$ } IV.

Or, in the supplemental triangle ACB, right-angled at C, there is
 Given the lat. of St. Julian's, or the leg $CB = 48^\circ 51'$.
 the diff. longitude, or the leg $CA = 66^\circ 10'$.

The solution falls under Article 140. Book IV.

To find the distance AB.

As radius,	Or, As radius	$= 90^\circ 00'$	10,00000
To co-f. either leg;	To co-f. diff. long. AC	$= 66^\circ 10'$	9,60646
So co-f. other leg,	So co-f. diff. lat. CB	$= 48^\circ 51'$	9,81825
To co-f. hyp.	To co-f. dist. AB	$= 74^\circ 35'$	9,42471

So that the dist. $AB = 74^\circ 35'$ is 4475 miles; which is less by 57 miles than the distance found by Mercator's sailing.

To find the angle of position at A. (IV. 139.)

As radius,	Or, As radius	$= 90^\circ 00'$	10,00000
To fin. leg AC;	To fin. diff. long. AC	$= 66^\circ 10'$	9,96129
So co-t. leg CB,	So co-t. diff. lat. CB	$= 48^\circ 51'$	9,94146
To co-t. op. $\angle A$.	To co-t. $\angle$ posit. at A	$= 51^\circ 22'$	9,90275

To find the angle of position at B.

As radius,	Or, As radius	$= 90^\circ 00'$	10,00000
To fin. leg CB;	To fin. diff. lat. CB	$= 48^\circ 51'$	9,87679
So co-t. leg AC,	So co-t. diff. long. AC	$= 66^\circ 10'$	9,64517
To co-t. op. $\angle B$.	To co-t. $\angle$ posit. at B	$= 71^\circ 36'$	9,52196

So that a ship sailing from the Island of St. Thomas must first shape her course S. $51^\circ 22'$ W.; and then by constantly altering her course towards the west, so as to arrive at Port St. Julian on a course S. $71^\circ 36'$ W. she will have sailed the shortest distance between those places.

106. CASE V. When the latitudes of the given places are both north, or both south.

EXAMPLE. What is the nearest distance between the Lizard and the Island of Bermudas; and also the angles of position at each place?

The Lizard in lat. $49^\circ 57'$ N. and long. $5^\circ 21'$ W.

Isl. Bermudas in lat. $32^\circ 35'$ N. and long. $63^\circ 32'$ W.

Diff. long. $58^\circ 11'$

By CONSTRUCTION. Plate XIII. Fig. 27.

Make $PA = 57^\circ 25'$, the co-lat. of Bermudas; $Pa = 40^\circ 03'$, the co-lat. of the Lizard; and (IV. 68) with the tang. of pa describe the arc aa .
 With

With the secant, of $58^{\circ} 11'$, the diff. long. (IV. 76), describe arcs from p and s, which give the center of the circle PCs, the meridian of the Lizard; its intersection with aa gives B the place of the Lizard.

Describe a great circle through A, B, D, (II. 72), and the intercepted arc AB is the distance fought; and the angles PAB, PBA, are the positions required.

The distance AB may be measured by (IV. 70); and the positions by (IV. 72).

Had the eastern place, the Lizard, been put on the primitive circle, the great circle AB would have been difficult to describe; and therefore the western place was put on the primitive circle, it being a matter of indifference which of the places is so taken.

COMPUTATION. In the oblique spheric triangle APB.

Given Bermudas's co-lat., $PA = 57^{\circ} 25'$
 Lizard's co-lat., $PB = 40^{\circ} 03'$
 Diff. longitude $\angle APB = 58^{\circ} 11'$ } Required the rest.

The solution falls under Art. 151. Book IV.

To find the distance AB.

As radius,	Or, As radius	= $90^{\circ} 00'$	10,00000
To co-f. giv. $\angle$;	To co-f. diff. long. $\angle APB$	= $58^{\circ} 11'$	9,72193
So tang. eith. side,	So tang. Berm. co-lat. PA	= $57^{\circ} 25'$	10,19442
To tang. M.	To tang. fourth arc	= $39^{\circ} 31'$	9,91640

Which take from Lizard's co-lat. = $40^{\circ} 03'$

Leaves a fifth arc = $0^{\circ} 32' = N.$

As co-f. M,	As co-f. fourth arc	= $39^{\circ} 31'$	0,11270
To co-f. N;	To co-f. fifth arc	= $0^{\circ} 32'$	9,99998
So co-f. side 1st used,	So fin. Bermudas lat.	= $32^{\circ} 35'$	9,73121
To co-f. side required.	To co-f. distance AB	= $45^{\circ} 44'$	9,84389

To find the angle of position PBA. (IV. 150).

As this angle is opposite to the side used in the first proportion, therefore the fourth and fifth arcs here used, are the same as above.

As fin. N,	As fin. fifth arc	= $0^{\circ} 32'$	2,03113
To fin. M;	To fin. fourth arc	= $39^{\circ} 31'$	9,80366
So tang. given $\angle$,	So tang. diff. long. $\angle APB$	= $58^{\circ} 11'$	10,20731
To tang. req. $\angle$.	To tang. $\angle$ posit. $\angle PBA$	= $89^{\circ} 29'$	12,04210

To find the angle of position PAB.

The other parts being found, this angle may be found by the proportion between opposite sides and angles. Thus:

As fin. PA,	Or, As fin. Bermudas's co-lat.	= $57^{\circ} 25'$	0,07437
To fin. $\angle PBA$;	To fin. $\angle$ pos. at Lizard	= $89^{\circ} 29'$	9,99998
So fin. BP,	So fin. Lizard's co-lat.	= $40^{\circ} 03'$	9,80852
To fin. $\angle PAB$,	To fin. $\angle$ pos. at Bermudas	= $49^{\circ} 47'$	9,88287

R 2

Or,

Or, working by Art. 150. Book IV. the same angles would be obtained.

Had the two first proportions been worked with the Lizard's latitude instead of Bermudas's, the same distance would have been found.

So the shortest distance between the Lizard and Bermudas is $45^{\circ} 44'$, or 2744 sea miles; which is 56 miles less than the distance found by Mercator's sailing.

And a ship to run this shortest tract must sail from the Lizard S. $89^{\circ} 29' W.$, and gradually lessen the course, so as to arrive at Bermudas on the rhumb bearing S. $49^{\circ} 47' W.$: whereas the direct course from one place to the other, as found by Mercator's sailing, is S. $68^{\circ} 09' W.$

107. CASE VI. *When one of the given places has north latitude, and the other has south latitude.*

EXAMPLE. *What is the nearest distance from the Island of St. Helena to the Island of Bermudas; and also the angles of position at each place?*

Island of Bermudas in lat. $32^{\circ} 35' N.$ and long. $63^{\circ} 32' W.$

Island of St. Helena in lat. $15^{\circ} 55' S.$ and long. $5^{\circ} 49' W.$

Diff. long. $57^{\circ} 43'$

By CONSTRUCTION. Pl. XIII. Fig 28.

Make $QA = 15^{\circ} 55'$, the lat. of St. Helena; describe the arc aa about P (IV. 68) with the tangent of $Pa = 57^{\circ} 25'$, the co-lat. of Bermudas.

Arcs described from P , s , with the secant of $57^{\circ} 43'$, the diff. long., will give the centre of the circle PCs , the meridian of Bermudas; and its intersection B with aa , is the place of Bermudas.

Describe a great circle through A , B , D ; the intercepted arc AB is the distance sought, which may be measured by IV. 70; and the angles PAB , ABS , are the positions required, which are to be measured as directed in Art. 72. Book IV.

COMPUTATION. In the oblique spheric triangle ABP .

Given $PA = 105^{\circ} 55'$, St. Helena's lat., added to 90° ; or its N. pol. dist.

$PB = 57^{\circ} 25'$, Bermudas's co-lat.

$\angle APB = 57^{\circ} 43'$, their difference of longitude.

To find the rest. The solution falls under Art. 150, 151. Book IV.

To find the distance AB.

As radius,	Or, As radius	$= 90^{\circ} 00'$	10,0000
To co-f. $\angle P$;	To co-f. diff. long.	$= 57^{\circ} 43'$	9,72763
So tang. PB ,	So tang. Berm. co-lat.	$= 57^{\circ} 25'$	10,19442
To tang. M .	To tang. fourth arc	$= 39^{\circ} 53'$	9,92205
	Which taken from	$= 105^{\circ} 55'$	$=$ St. Helen's N.
	Leaves a fifth arc	$= 66^{\circ} 02'$	$=$ N. [polar dist.]
As co-f. M ,	Or, As co-f. fourth arc	$= 39^{\circ} 53'$	0,11501
To co-f. N ;	To co-f. fifth arc	$= 66^{\circ} 02'$	9,60874
So co-f. PB ,	So sin. Bermudas lat.	$= 32^{\circ} 35'$	9,73121
To co-f. AB .	To co-f. distance	$= 73^{\circ} 26'$	9,45496

To

To find the angle of position PAB.

The fourth and fifth arcs being found as before.

As fin. N,	Or, As fin. fifth arc	= 66° 02'	0.03916
To fin. M;	To fin. fourth arc	= 39 53	9.80701
So tang. $\angle P$,	So tang. diff. long.	= 57 43	10.19944
To tang. $\angle A$.	To tang. $\angle$ position PAB	= 48 00	<u>10.04561</u>

To find the angle of position ABP.

As fin. BA,	Or, As fin. of dist.	= 73° 26'	0.01841
To fin. $\angle P$;	To fin. diff. long.	= 57 43	9.92707
So fin. PA,	So fin. St. Helena's N. P. dist.	= 105 55	<u>9.98302</u>
To fin. $\angle ABP$.	To fin. $\angle$ position ABP	= 58° 01'	<u>9.92850</u>

But because the given difference of latitude is less than 90° , and the side PA greater, the angle ABP must be greater than 90° ; and is, therefore, $121^\circ 59'$, which is the supplement of $58^\circ 01'$.

So that were a ship to sail from St. Helena to Bermudas on the arc of a great circle, she must first shape her course N. $48^\circ 00'$ W., and gradually alter it from the north towards the west, so as to arrive at Bermudas on a course N. $58^\circ 01'$ W., after having run $73^\circ 26'$, or 4406 sea miles.

The course found by Mercator's sailing is N. $48^\circ 45'$ W., and the distance is 4414 miles.

By this it appears, that when the places are one in N. latitude, and the other in S. latitude, and neither of them far from the equator, there is but a small difference between the results found by Mercator's and great circle sailing: for near the equator the rhumb lines do not differ greatly from great circles.

From the solution of the foregoing cases it is plain, that to sail on the arc of a great circle, the ship must continually alter her course. But as this is a difficulty too great to be admitted into the practice of Navigation, it has been thought sufficiently exact to effect this business by a kind of approximation; that is, by a method which nearly approaches to sailing on a great circle.

108. The principle upon which this approximation is founded, is that in small arcs, the difference between the arc and its chord, or tangent, is so small, that they may be taken one for the other in any nautical operations.

Lat. of the place sailed from is $37^{\circ} 00' N.$ the long. $22^{\circ} 56' W.$
 Lat. of the place bound to is $37^{\circ} 00' N.$ the long. $76^{\circ} 23' W.$

The diff. of long. $53^{\circ} 27'$

The figure being described, and the computation made as in Art. 104. the distance BA is found to be $42^{\circ} 06'$, and the $\angle A$ or $\angle B = 73^{\circ} 09'$, the angle of position. Plate XIII. Fig. 29.

Now the triangle APB, being isosceles, the perpendicular PI falls in the middle of AB; and the latitudes, courses, and distances, being known in running the half BI, those in the half IA will also be known.

Let the points $a, b, c, d, \&c.$ be the places arrived at on each alteration of five degrees of longitude: then will the arcs $Pa, Pb, Pc, Pd, \&c.$ be the respective co-latitudes of those places, and are the hypotenuses of the right-angled spheric triangles $PIa, PIb, PIC, PID, \&c.$

In the triangle $PIB.$		As rad.	$= 90^{\circ} 00'$	10,00000
Given	$PB = 53^{\circ} 00'$	To sin. PB	$= 53^{\circ} 00'$	9,90235
	$\angle PBI = 73^{\circ} 09'$	So sin. $\angle B$	$= 73^{\circ} 09'$	9,98004
To find $PI.$		To sin. PI	$= 49^{\circ} 51'$	9,88329

Now $\angle IPB = \left(\frac{53^{\circ} 27'}{2}\right) 26^{\circ} 43\frac{1}{2}'$; $\angle IPa = 21^{\circ} 43\frac{1}{2}'$; $\angle IPb = 16^{\circ} 43\frac{1}{2}'$;

$\angle IPc = 11^{\circ} 43\frac{1}{2}'$; $\angle IPd = 6^{\circ} 43\frac{1}{2}'$, are the several polar angles.

	$21^{\circ} 43\frac{1}{2}'$	$16^{\circ} 43\frac{1}{2}'$	$11^{\circ} 43\frac{1}{2}'$	$6^{\circ} 43\frac{1}{2}'$
Then rad.	$= 90^{\circ} 00'$	10,00000	10,00000	10,00000
To co-t. PI	$= 49^{\circ} 51'$	9,92612	9,92612	9,92612
So co-f. polar angle		9,96800	9,98123	9,99084
		9,99700		
To tang. lat.		9,89412	9,90735	9,91696
		9,92312		
Which are	$38^{\circ} 05'$	$38^{\circ} 56'$	$39^{\circ} 33'$	$39^{\circ} 57'$

The degrees and min. set over each column, are the polar angles used in that proportion, and the corresponding latitudes stand at the bottom.

III. The first term of these proportions being radius, and the second term constant, the operations may be very expeditiously performed thus:

On a slip of paper let the log. of the second or constant term be written of the same size with the printed figures; apply this log. cot. successively to the log. co-sines of the polar angles: Then the sum of the two logs. being written down each time, will give the log. tangents of the several latitudes arrived at.

By this method, each proportion will be worked by writing down only one line.

Hence it appears, the ship must first sail from the lat. $37^{\circ} 00' N.$ to lat. $38^{\circ} 05' N.$; thence to lat. $38^{\circ} 56' N.$; thence to lat. $39^{\circ} 33' N.$; thence to lat. $39^{\circ} 57' N.$; thence to lat. $40^{\circ} 09' N.$, which is the greatest latitude she must go to; and from thence she must proceed through the latitudes $39^{\circ} 57'$, $39^{\circ} 33'$, $38^{\circ} 56'$, $38^{\circ} 05'$, and so to $37^{\circ} 00'$, the parallel she set out from, and in which she is to find the place she is bound to.

R 4

Now

Now between these several latitudes, with the respective differences of longitude, find, by Mercator's sailing, Art. 57, the courses and distances.

If the results of the several operations, in the questions of great circle sailing, be entered in such a table as the following, it will be found of some convenience to the operator.

Polar angles.	Succell. longs.	Succell. lats.	Diff. long.	Diff. lat.	Merid. parts.	Merid. d. lat.	Cour.	Dist.
$\angle IPB$ $26^{\circ} 43\frac{1}{2}'$	$22^{\circ} 56'$	$37^{\circ} 00'$			2392,6			
$\angle IPa$ $21^{\circ} 43\frac{1}{2}'$	$27^{\circ} 56'$	$38^{\circ} 05'$	300	65	2474,6	82,0	74,43	246,6
$\angle IPb$ $16^{\circ} 43\frac{1}{2}'$	$32^{\circ} 56'$	$38^{\circ} 56'$	300	51	2539,8	65,2	77,44	240,0
$\angle IPc$ $11^{\circ} 43\frac{1}{2}'$	$37^{\circ} 56'$	$39^{\circ} 33'$	300	37	2587,6	47,8	80,57	235,2
$\angle IPd$ $6^{\circ} 43\frac{1}{2}'$	$42^{\circ} 56'$	$39^{\circ} 57'$	300	24	2618,8	31,2	84,04	232,2
	$49^{\circ} 39\frac{1}{2}'$	$40^{\circ} 09'$	403,5	12	2634,5	15,7	87,46	307,9
								1261,9

In the first column are the angles at the pole contained between the perpendicular and the several meridians differing by 5° of longitude.

In the second column, the departed longitude $22^{\circ} 56'$ being increased by the differences of longitude, make the successive longitudes come to.

In the third column are the successive latitudes passed through in sailing from the place set out from to the greatest latitude.

In the fourth and fifth columns are the differences between the longitudes and latitudes in the second and third columns.

In the sixth column are the meridional parts to the successive latitudes; and in the seventh column are the meridional diff. of latitudes.

The eighth and ninth columns contain the courses and distances between the places answering to the second and third columns.

The numbers in the third, eighth, and ninth columns, are found by working the logarithmic proportions on a waste paper; but the work is here omitted, as it is so easily supplied.

Now the column of distances being summed up amounts to 1261,9; which being doubled gives 2523,8 miles for the distance between the two places.

And the courses the ship must steer are, 1st. N. $74^{\circ} 43' W.$; 2d. N. $77^{\circ} 44' W.$; 3d. N. $80^{\circ} 57' W.$; 4th. N. $84^{\circ} 04' W.$; 5th. N. $87^{\circ} 46' W.$; 6th. S. $87^{\circ} 46' W.$; 7th. S. $84^{\circ} 04' W.$; 8th. S. $80^{\circ} 57' W.$; 9th. S. $77^{\circ} 44' W.$; 10th. S. $74^{\circ} 43' W.$: and on these courses she must run the respective distances standing against them.

112. QUESTION II. *It is proposed that a ship, bound from the Lizard to a place in lat. $32^{\circ} 25' N.$ and long. $66^{\circ} 45' W.$ shall sail on a great circle, and alter her course at every five degrees of longitude; required the latitudes through which the ship is to pass, and also the course and distance between each.*

The Lizard's lat. is $49^{\circ} 57' N.$ Long. $5^{\circ} 21' W.$ }
 Lat. place bound to is $32^{\circ} 25' N.$ Long. $66^{\circ} 45' W.$ } Diff. long. $61^{\circ} 24'.$

Having described the figure, Plate XIII. Fig. 30, and found the $\angle PAB = 49^{\circ} 35'$, the $\angle PBA = 87^{\circ} 15'$, and the side $AB = 47^{\circ} 54'$, as in Art. 106.

Draw

Draw PI at right angles to ABD.

(IV. 73)

In the equator, lay off from the center the tangents of 5, 10, 15, 20, &c. to 55 degrees; and those points give the centers to the arcs of colat. to every 5° diff. longitude.

(IV. 75)

To find the perpend. PI.

As rad.	= 90° 00'	10,00000
To fin. PA	= 57 35	9,92643
So fin. LA	= 49 35	9,88158
To fin. PI	= 40 00	9,80801

To find the polar angle API.

As rad.	= 90° 00'	10,00000
To tang. LA	= 49 35	10,06978
So cos. AP.	= 32 25	9,72922
To cot. LA	= 57 48	9,79900

Now the polar angle API, or the diff. long. between the perpend. PI and the meridian of the place bound to, 57° 48', being taken from 61° 24', the whole diff. long. leaves 3° 36' for the diff. long. between the Lizard and the point I. Also 5°, the proposed alteration of longitude, being subtracted as often as can be from 57° 48', leaves the several polar angles; with which, and the perpendicular PI the several latitudes arrived at are found by Art. III.

Then having those latitudes, and the differences of longitude between them, find the successive courses and distances by Art. 57.

Let the several results be placed as in the following table; the logarithmic work being performed on a waste paper is here omitted.

Also, suppose the small letters in the figure supplied.

Polar angles.	Success. longs.	Success. lats.	Diff. long.	Diff. lats.	Merid. parts.	Merid. d. lat.	Courses	Dist.
	5° 14'	49° 57'			3469,8			
∠IPB 3° 36'	8 50	50 00	216	3	3474,5	4,7	88° 45'	137,5
∠IPa 2 48	11 38	49 58	168	2	3471,4	3,1	88 56	107,4
∠IPb 7 48	16 38	49 44	300	14	3449,7	21,7	85 52	194,2
∠IPc 12 48	21 38	49 17	300	27	3408,1	41,6	82 06	196,4
∠IPd 17 48	26 38	48 37	300	40	3347,2	60,9	78 31	200,6
∠IPe 22 48	31 38	47 42	300	55	3264,7	82,5	74 37	207,3
∠IPf 27 48	6 38	46 31	300	71	3160,4	104,3	70 50	216,3
∠IPg 32 48	41 38	45 03	300	88	3034,2	126,2	67 10	226,8
∠IPh 37 48	46 38	43 17	300	106	2885,4	147,8	63 46	239,8
∠IPi 42 48	51 38	41 10	300	127	2714,9	171,5	60 15	255,9
∠IPk 47 48	56 38	38 41	300	149	2520,5	194,4	57 03	273,9
∠IPl 52 48	61 38	35 46	300	175	2300,7	219,8	53 46	296,1
	66 38	32 25	300	201	2058,0	242,7	51 02	319,6
								2871,8

Now the sum of the several distances make 2871,8 miles.

But the distance in the arc of a great circle is 2874 miles.

The difference of the two methods is therefore 2,2 miles.

In this example it was judged necessary to keep the fractional place in the meridional parts, in order to have the distances more accurate.

113. QUESTION III. A ship being bound from a place in lat. 16° 00' S. long. 6° 15' W. to a place in lat. 32° 25' N. long. 66° 38' W. it is proposed she shall sail near the arc of a great circle passing through those places, and

and alter her course at every 5° of longitude: required the latitudes where those courses are to be altered, and also the course and distance between each place of alteration.

Lat. of place sailed from 16° 00' S. Long. 6° 15' W. } Diff. long = 60° 23'.
 Lat. of place bound to 32 25 N. Long. 66 38 W. }

Having described the figure, Plate XIII. Fig. 31. and found the $\angle PEA = 120^\circ 15'$; $\angle BAB = 49^\circ 20'$; and the distance $AB = 75^\circ 19'$; as in Art. 107.

In the equator QF, lay off from F the tangents of $5^\circ 10' 15''$, &c. to 55° ; and those points will give the centers to the meridians passing through every five deg. of long. between the two places.

To find the perpendicular.

As rad.	= 90° 00'	10,00000
To sin.	PB = 57 35	9,92643
So sin.	$\angle PBI = 59 45$	9,93643
To sin.	PI = 46 49	9,86286

To find the polar $\angle BPI$.

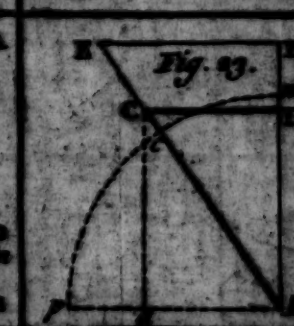
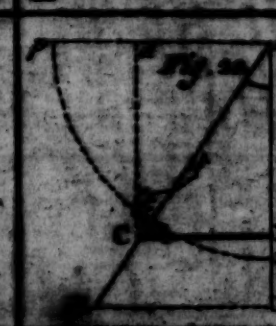
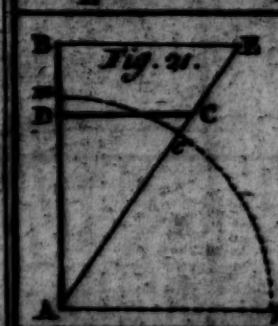
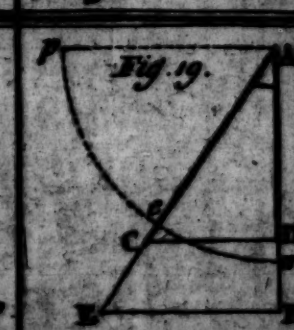
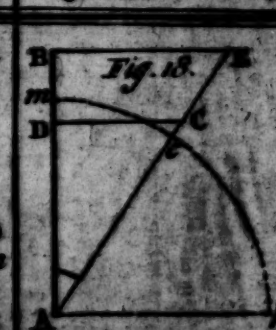
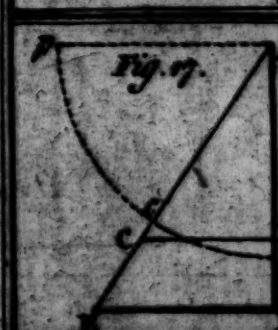
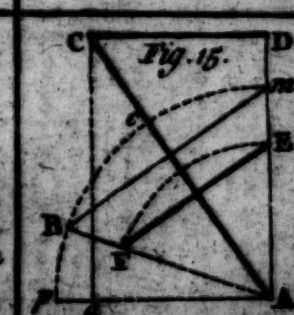
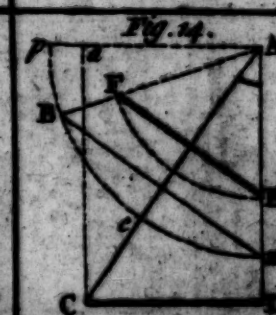
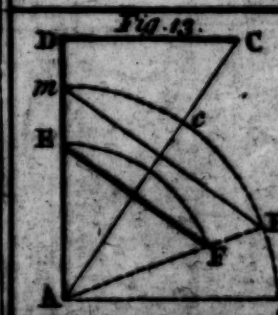
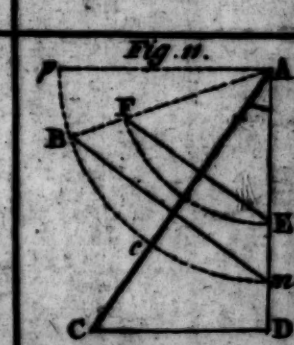
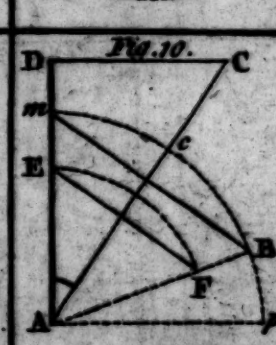
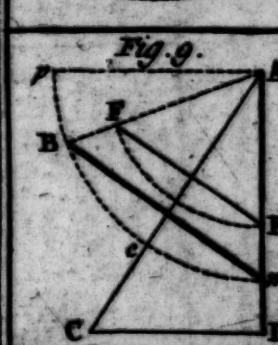
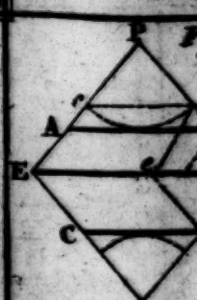
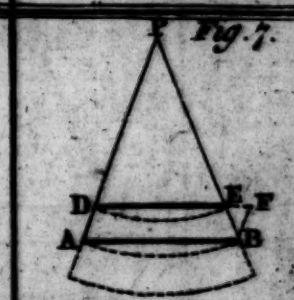
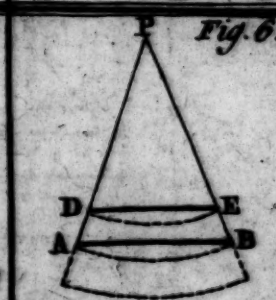
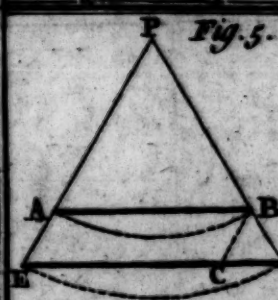
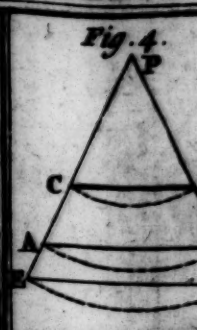
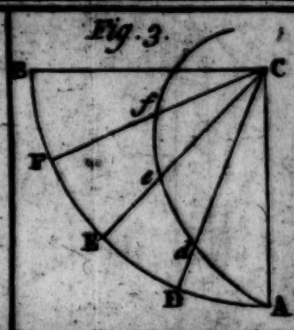
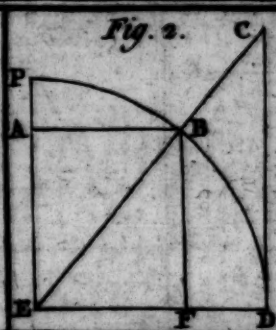
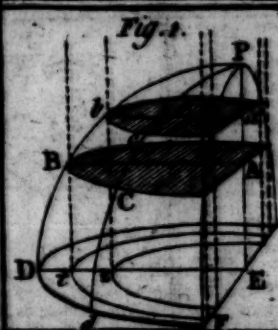
As rad.	= 90° 00'	10,00000
To co-f.	BP = 57 35	9,72922
So tang.	$\angle PBI = 59 45$	10,23419
To cot.	$\angle BPI = 47 25$	9,96341

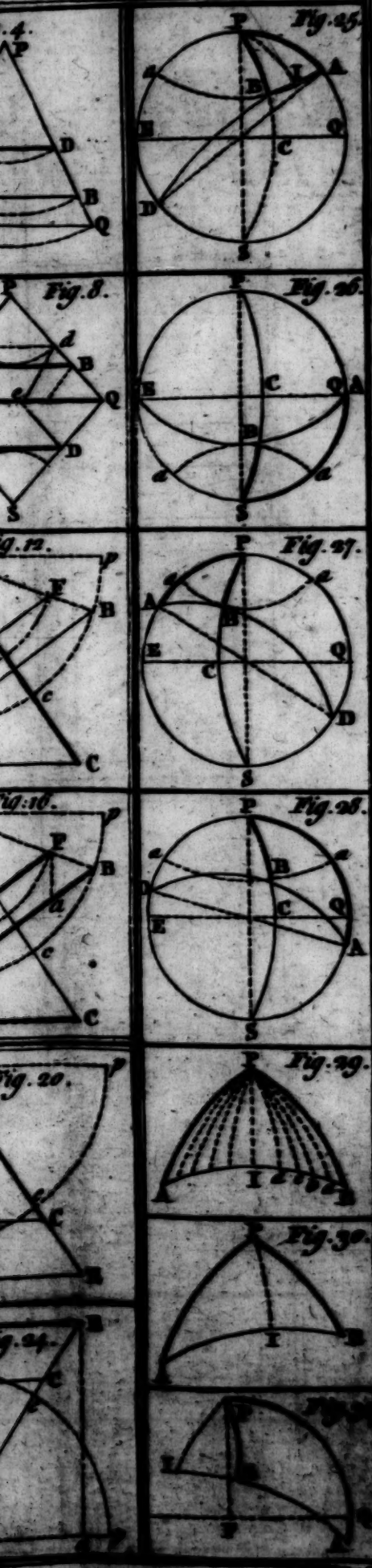
Now the several polar angles, longitudes, latitudes, diff. of longs., diff. of lats., mer. parts, mer. diff. of lats., courses and distances, being computed on a waste paper, their results are to be entered in a table as follows:

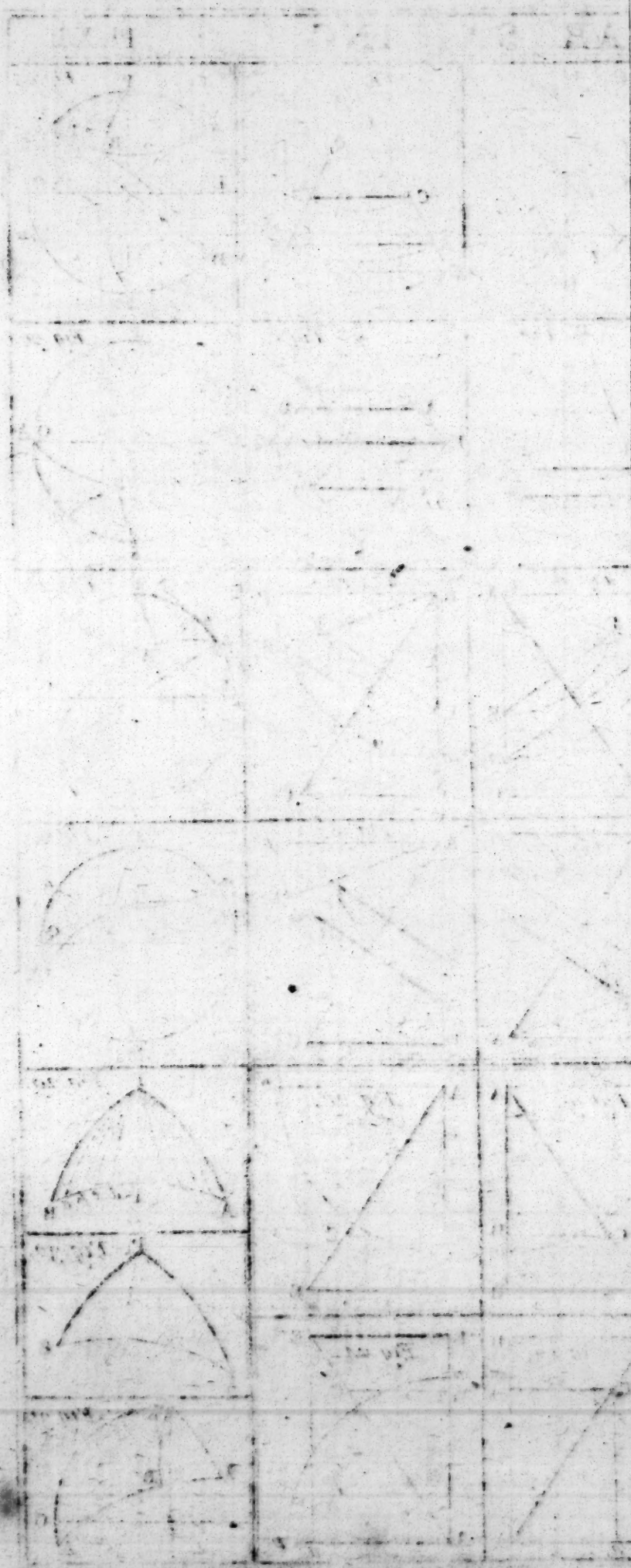
Polar angles.	Succell. longs.	Succell. lat.	Diff. long.	Diff. lats.	Mer. parts.	Mer. d. lat.	Courses.	Dist.
	6° 15'	16° 00' S						
$\angle IPl = 102^\circ 48'$	11 15	11 45	300	255	973	264	48° 39'	386,0
$\angle IPk = 97 48$	16 15	7 16	300	269	709	272	47 48	400,5
$\angle IPi = 92 48$	21 15	2 38	300	278	437	279	47 05	408,3
$\angle IPb = 87 48$	26 15	2 04 N	300	282	158	282	46 46	411,7
$\angle IPg = 82 48$	31 15	6 43	300	279	124	280	46 58	408,8
$\angle IPf = 77 48$	36 15	11 13	300	270	404	273	47 42	402,1
$\angle IPe = 72 48$	41 15	15 31	300	258	677	266	48 26	388,8
$\angle IPd = 67 48$	46 15	9 32	300	241	943	252	49 51	374,7
$\angle IPC = 62 48$	51 15	23 13	300	221	1195	238	51 34	355,5
$\angle IPb = 57 48$	56 15	26 34	300	201	1433	221	53 37	338,9
$\angle IPa = 52 48$	61 15	29 34	300	180	1654	204	55 47	320,1
	66 38	32 25	323	171	1858	200	58 14	324,8
					2058			4519,3

114. The track of a ship when directed nearly in the arc of a great circle, as in the preceding articles, may be delineated on the Mercator's chart, by marking on it, by the help of the latitudes and longitudes, the successive places where the ship is to alter her course; then those places or points being joined by right lines will shew the path, along which the ship is to sail under the proposed circumstances.

Thus in Plate XII. the route proposed in question II. Art. 110, is drawn from the Lizard to Bermudas, the situations of those two places, as they are laid down in that chart, being those proposed in this example. And notwithstanding this track on the chart appears much longer than the rhumb passing through those two places, yet it must be remembered, that these rhumb lines are only the representations of curves on the sphere, the absolute lengths of which are not hereby expressed.







SECTION VIII.

Of the errors arising in the cases of Sailing, upon the supposition that the Earth is not a Sphere.

115. The reasoning and conclusions in the preceding Sections of this Book, have been delivered in the opinion that the Earth is a sphere; but it has appeared from many observations made since the Year 1672, that its figure is not that of a perfect sphere; its axis, or polar diameter, being shorter than the equatorial diameter.

This notion first arose from observation made on pendulum clocks; which being fitted to beat seconds in the latitudes of Paris and London, were found to move slower as they approached the equator; and the pendulums were obliged to be shortened about $\frac{1}{2}$ parts of an inch, to agree with the times of the stars passing the meridian (V. 264). This difference in the lengths of the pendulum appearing to those great men, *Huygens* and *Newton*, to be a much greater quantity than could arise from the alteration by heat only, they, separately, discovered that the Earth was flatted at the poles*; and Sir Isaac Newton has shewn in his *Principles of Natural Philosophy*, that this flatness is about $17 \frac{1}{10}$ miles, and that the polar diameter is to the equatorial diameter, as 229 is to 230.

* To give the learner a notion how this conclusion was drawn, it has been thought proper to add what follows, collected chiefly from Newton's Princip. Book III. Prop. 18, 19, 20.

CENTRIPETAL FORCE is, like *Gravitation*, that power by which heavy bodies tend towards a center.

CENTRIFUGAL FORCE is that, by which bodies recede from a center; in the manner that the particles of water and thrums fly from a whirled mop.

The swifter the mop is whirled, the greater is the centrifugal force, and the particles fly off with greater velocity.

The diurnal rotation of the Earth gives to all its parts a centrifugal force, by which the parts receding from the axis endeavour to ascend about the equator; for if it was not higher there, the seas, from the centrifugal force, subsiding about the poles and rising towards the equator, would lay all things there under water.

Bodies acted on at the same time by a centripetal and a centrifugal force, have their power of gravitation lessened.

A falling body moves swifter as it approaches the Earth.

Gravitating bodies move swifter as their gravity increases; and the contrary.

A plummet at the end of a string, or a pendulum, when made to swing, returns to its lowest point by its weight or gravity.

And the slower the vibration of the pendulum is, the less its gravitation.

Consequently, the same pendulum vibrating slower than would arise from its lengthening by heat, shews a decrease of gravity in that pendulum; and as this decrease of gravity became gradually greater in approaching the equator, the Earth must be more prominent there than at the poles; that is, the Earth is a little flatted at the poles.

116. But,

116. But, notwithstanding the scientific deductions of this most accurate mathematician, many of the philosophers in France embraced the strange notion of the Earth's being of an oblong figure, the polar diameter being the longer. And as these different notions were supposed to retard the general progress of science in France, their KING resolved that the affair should be determined by actual mensuration at his own expence. Accordingly, about the year 1735, two companies of the most able mathematicians of that nation were appointed; the one to measure a degree of a meridian as near the equator as they could; and the other company to perform a like operation as near the north pole as could be conveniently attempted.

117. For, the Earth being supposed a spheroid, and consequently every meridian an ellipsis, it was known, as a mathematical problem, that the respective measures of a degree of a meridian in each of two known distant latitudes being had, the relation of the diameters could be found; and, that if the measured lengths of those degrees increased towards the pole, the figure would be that of an oblate spheroid, such as *Newton* assigned; otherwise, its figure would be an oblong spheroid, such as was insisted on by *Cassini*. Now the length of a degree of the meridian between Paris and Amiens, or which had its middle point in latitude $49^{\circ} 22' N$, was understood to be 57060 toises; * having been measured by *Picart*, in 1670, and being re-examined by *Cassini* in 1701. And this length was to be compared with the length of a degree measured at the polar circle and the equator.

118. The gentlemen appointed for the northern expedition were Messieurs *Maupertuis*, *Clairaut*, *Camus*, *le Monnier*, and *Outhier* of France; who were joined by *M. Celfus*, an eminent astronomer in Sweden. The company proceeded to Swedish Lapland, and began their operations in July 1736, which they finished in the following May; and among many other curious and useful particulars they obtained the measure of a degree, the middle point of which was in the latitude of $66^{\circ} 20' N$., and found it to be 57438.9 toises, when reduced to the level of the sea; and discovered that *the Earth is flatted at the Poles*, the proportion of the equatorial diameter to the polar diameter being as 1 to 0.9891.

119. The other company of gentlemen, who were ordered to the south, consisted of Messieurs *Godin*, *Bouguer*, and *la Condamine*, of France; to whom were joined *Don Jorge Juan*, and *Don Antoine de Ulloa*, of Spain. These mathematicians departed from Europe about the middle of the year 1735, and began their operations, in the province of Quito in Peru, about October, 1736, and finished them in eight Years, after many interruptions. Among the valuable pieces of knowledge resulting from their observations, it appears that *the Earth is flatted at the poles*.

120. The Spanish gentlemen, who published their account separately, assign 56767.8 toises for the measure of a degree of the meridian at the equator, and 266 to 265; or 1 to 0.99624 for the ratio of the equatorial to the polar diameters of the earth.

* A measure containing 6 French feet, or 6 feet $4\frac{1}{2}$ inches English, nearly: the French foot being to the English foot as 1.068 to 1.

M. Bouguer gives for the measured length of a degree of the meridian at the equator 56753 toises, when reduced to the level of the sea, and makes the diameter of the equator to that at the poles, as 179 to 178; or as 1 to 0,99441.

M. de la Condamine gives for the measure of a degree under the equator, a length of 56749 toises.

M. De la Caille, being at the *Cape of Good Hope* in 1752, found the length of a degree of the meridian latitude $33^{\circ} 18\frac{1}{2}'$ S. to be 57037 toises.

In 1755, Father *Boscovich* found the length of a degree in latitude 43° N. to be 56972 toises, as measured between Rome and Rimini in Italy. In the year 1740, Messieurs Cassini, the younger, and De la Caille again examined the former measures in France; and, after making all the necessary corrections, they found the measure of a degree, the middle of which is in $49^{\circ} 22'$ N., to be 57074 toises; and the length of a degree of the meridian in latitude 45° to be 57050 toises.

121. M de *Maupertuis* has added to his narrative of the observations made by himself and his associates in the north, a method of computing the proportion between the polar and equatorial diameters, from the measurements taken in any two different latitudes; but he solves the problem by an approximation only. Among the curious problems communicated by Mr. *Jones* to Mr. *Gardiner*, and published by him in his quarto edition of logarithmic tables, there is the result of a true solution of this problem, but without either analysis or demonstration. While I was intent on an investigation of the solution, Dr. *Pemberton* was pleased to put into my hands a very elegant one of it by his friend Dr. *Letherland*, with leave to communicate it to the public; and I shall accompany it with such other problems, as are requisite for applying this solution to the purposes of navigation, the whole composing the series of problems following.

122.

PROBLEM I.

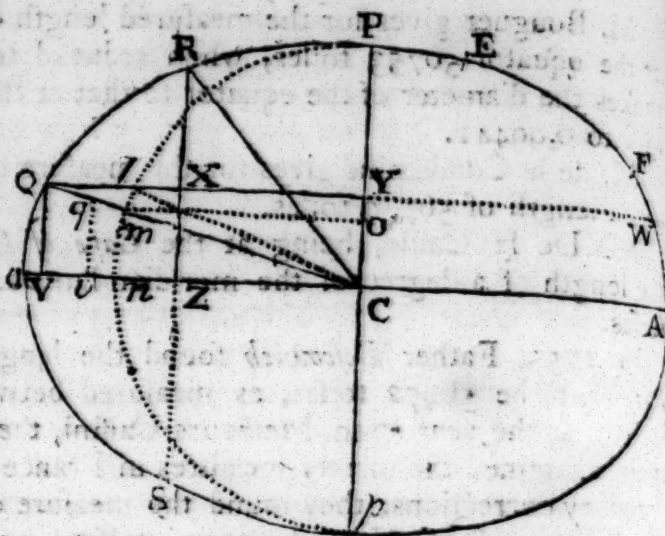
Supposing the Earth to be a spheroid, having its axis less than the equatorial diameter, to find the proportion between the axis and that diameter from measures of a degree of the meridian taken in two different latitudes.

ANALYSIS.

Let $apAp$ be an ellipsis representing a section of the Earth through its axis pp ; the equatorial diameter, or the greater axis of the ellipsis, being aa ; let E and F be two places, where the measure of a degree has been taken: these measures are proportional to the radii of curvature in the ellipsis at those places; and if cQ , cR are conjugates to the diameters, the vertices of which are E and F , cQ will be to cR in the subtriplicate ratio of the radius of curvature in E to the radius of curvature in F *, and therefore in a given ratio one to the other. Then QV

* See Milne's Conic Sect. Cor. I. Prop. IV. Part VI.

and RZS being drawn parallel to Pp , and $QXYW$ parallel to aA at the angles QCP , RCP , are the latitudes at E and F ; so that these angles, and the ratio of CQ to CR being given, the rectilinear figure $CVQXR$ is given in species: and the ratio of $VC^2 - ZC^2 (= QX \times XW)$ to $RZ^2 - QV^2 (= RX \times XS)$ is given, which is the ratio of CA^2 to CP^2 . Therefore the ratio of CA to CP is given.



Hence, if the sine and co-sine of the greater latitude be each augmented in the subtriplicate ratio of the measure of the degree in the greater latitude to that in the lesser, then the difference of the squares of the augmented sine, and the sine of the lesser latitude, will be to the difference of the squares of the co-sine of the lesser latitude and the augmented co-sine, in the duplicate ratio of the equatorial to the polar diameter.

For cq being taken in CQ equal to CR , and qv drawn parallel to QV ; cv and vq , cz and zr will be the sines and co-sines of the respective latitudes to the same radius; and cv , vq will be the augmentations of cv and cq in the ratio named.

123.

COROLLARY I.

If one of the degrees measured is at the equator, the co-sine of the latitude of the other being augmented in the subtriplicate ratio of the degrees, the tangent of the latitude will be to the tangent answering to the augmented co-sine in the ratio of the greater axis to the lesser.

For supposing the place out of the equator to be E ; if the semicircle $p l m n p$ be described, and lc joined, and mo drawn parallel to ac ; co is the co-sine of the latitude to the radius cp ; and cy that co-sine augmented in the ratio named; yq being to yl , that is, ca to cn or cp , as the tangent of the angle ycq ; the latitude of the point E , to the tangent of the angle ycl , appertaining to the augmented co-sine.

124.

COROLLARY II.

In this case, half the *latus rectum* of the greater axis aA , being the radius of curvature in A , is given in magnitude from the degree measured there; and thence the axes themselves will be given in magnitude.

125.

COROLLARY III.

Hence also the proportion of the axes being given from any two measurements, the *latus rectum* of the greater axis, and the axes themselves, will be given in magnitude. For if an angle be taken, the tangent of which

which shall be to the tangent of either latitude, as the lesser axis to the greater, the measure of a degree in that latitude, will be to the measure of a degree at the equator, in the triplicate ratio of the co-sine of this angle to the co-sine of the latitude.

Thus E being one of the places measured, the tangent of the angle YCL will be to the tangent of YQ , the latitude of the point E, as YL to YQ , that is, as the lesser axis to the greater; and $CQ : CL :: s, CL : Y : s, CQ : : \cos. LCY : \cos. QCY$, Q^c being to CL^c (CP^c) as the radius of curvature in E to the radius of curvature in A, that is, as the measure of a degree in E to the measure of a degree in A.

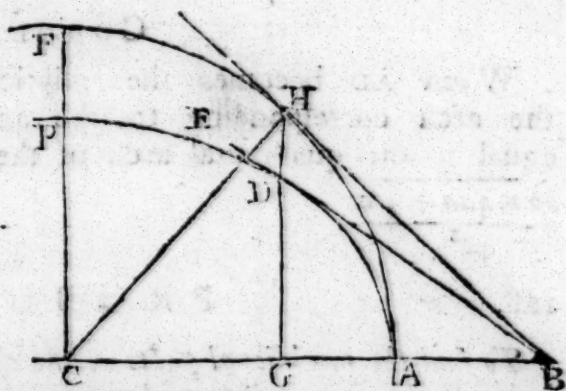
And thus both the figure and magnitude of the Earth may be deduced from any two measurements given.

126

PROBLEM II.

The Earth being supposed a spheroid, to find the semi-diameter of a parallel to the equator in any given latitude.

Let PDA be one fourth part of an elliptical meridian, where CA, the greater semi-axis, is the radius of the Earth's equator; and let BE be drawn to touch the ellipsis in D, and make with CA an angle CBD equal to the complement of the latitude given; then is D the place on the Earth having the given latitude; and the circular quadrant AF being described with the radius CA, let GDH be drawn parallel to the lesser semi-axis CP of the ellipsis; then BH, CH being joined, BH touches the arch AF in H, and is perpendicular to CH.



Now as $GD : GH$ (that is, $CP : CA$) $:: \tan. \angle GBD : \tan. \angle GBH$
 $:: \text{co-t. latitude} : \text{co-t. } \angle GCH$.
Hence the angle GCH is given; and radius is to the co-sine of the $\angle GCH$, as CH to CG. Whence CG is given, which is equal to the semidiameter of the circle passing through D, parallel to the equator.

127.

PROBLEM III.

The spheroidal figure of the Earth being supposed, to measure the elliptic arch corresponding to any given latitude.

M. Clairaut, one of the gentlemen engaged in the northern expedition, obliged me, when he was in London, in the year 1753, with the following series for measuring an elliptic arch.

"If in the preceding figure AC be denoted by a , CP by b , and aa —
 bb by c ; then, S denoting an arch in a circle the radius of which is
"unity,

" unity, which will measure the angle GDB, the latitude of the point D,
 " AD will be equal to

$$\text{" } \frac{b}{a} + \frac{3bbcc}{4a^3} + \frac{45bbcc^2}{64a^5} \&c. \times S - \frac{3bbcc}{8a^3} + \frac{15bbcc^2}{32a^5} \times \text{fin. } 2S + \frac{15bbcc^2}{256a^5}$$

" $\times \text{fin. } 4S \&c.$

" But in regard to the earth, all the powers of c above cc may be neglected, and the arch AD considered as equal

$$\text{" to } \frac{bb \times 4aa + 3cc}{4a^3} \times S - \frac{3bbcc}{8a^3} \times \text{fin. } 2S.$$

$$\text{" Or to } \frac{bb \times 4aa + 3cc}{4a^3} \times S - \frac{3bbcc}{8a^3} \times \frac{\text{tabular fine of twice the lat.}}{\text{radius}}$$

Whence if a circle be constituted, the radius of which is $\frac{bb \times 4aa + 3cc}{4a^3}$, then in this circle, the arch which measures the latitude, will exceed AD by $\frac{3bbcc}{8a^3} \times \frac{\text{tab. fine of twice the lat.}}{\text{radius}}$, that is, this excess will be to $\frac{3bbcc}{8a^3}$ as the fine of twice the latitude to radius.

COROLLARY.

When AD becomes the elliptical quadrant AP, the fine of twice the arch corresponding to the angle GDB vanishing, AP will be equal to the quadrantal arch of the said circle, the radius of which is $\frac{bb \times 4aa + 3cc}{4a^3}$.

128.

PROBLEM IV.

To find the meridional parts in the chart of Mercator's form for any given latitude, the earth being a spheroid.

The late Mr. Maclaurin, in his *Treatise on Fluxions**, has given this rule for reducing the meridional parts of the sphere to the spheroid; take an arch the fine of which is to the fine of the latitude, in the proportion of the distance of the foci in the generating ellipsis, to the greater axis; and diminish the meridional parts in the sphere by a number, which shall be to the spherical meridional parts appertaining to this arch in the same proportion.

But in the Earth this arch will be so small, that its fine, the arch itself, and the spherical meridional parts, will not differ sensibly from each other: whence the number to be deducted from the spherical meridional parts appertaining to the latitude shall be to the number of minutes contained in the fine of the latitude in the duplicate ratio of the distance of the foci to the greater axis. Therefore in the preceding proposition c being half the distance between the foci, the reduction of the meridional parts in the sphere to the spheroid, will be $\frac{cc}{aa} \times \frac{3437\frac{1}{2} \text{ fin. lat.}}{\text{radius}}$.

* Article 898. See also Phil. Transact. Vol. 41, page 808.

Or in the figure to Proposition II. $\frac{\overline{CA}^2 - \overline{CP}^2}{\overline{CA}^2} \times \frac{3437\frac{1}{2} \text{ fin. lat.}}{\text{radius.}}$

Application of these problems to the several measurements above-mentioned.

127. For finding the ratio between the two axes of the Earth by Prob. I. Let E denote the greater, and F the lesser of the two latitudes, M and N.

the respective measures taken in each : and let o denote $\sqrt[3]{\frac{M}{N}}$.

Then $\sqrt{\frac{s's'F - O^2 \times s's'E}{O^2 \times s's'E - s's'F}}$ is $\frac{\text{lesser axis.}}{\text{greater axis.}}$

Also if M represent the measure in a latitude denoted by E, and N the measure at the equator ; let A denote an angle, the measure of which is $\sqrt[3]{\frac{M}{N}} \times s's'E$.

Then $\frac{t_A}{t_E}$ is $\frac{\text{lesser axis}}{\text{greater axis}}$.

129. The lengths of a degree of a meridian, obtained by actual measurement in different latitudes, are the following.

Mauertuis and associates in lat. $66^\circ 20'$ found $M=57438$ toises.

Cassini and De la Caille	$\left\{ \begin{array}{l} 49 \ 22 \\ 45 \ 0 \end{array} \right.$	$\left\{ \begin{array}{l} M=57074 \\ M=57050 \end{array} \right.$
Boscovich	$\left\{ \begin{array}{l} 43 \ 0 \\ 33 \ 18 \end{array} \right.$	$\left\{ \begin{array}{l} M=56972 \\ M=57037 \end{array} \right.$
De la Caille		
Juan and Ulloa	$\left. \begin{array}{l} \\ \\ \end{array} \right\} \text{at the equator}$	$\left\{ \begin{array}{l} M=56768 \\ M=56753 \end{array} \right.$
Bouguer		
De la Condamine		$\left\{ \begin{array}{l} M=56749 \end{array} \right.$

Now by comparing the 1st with each of the following ; the 2d with each of the following ; and in like manner the 3d, 4th, and 5th, with each of the following, there will arise 25 results, each shewing the relation of those axes or diameters ; which results are here annexed to be compared.

I. Comparing the 1st with each of the following.

Putting E for $66^\circ 20'$, and F for each of the following. Then log. of o will be $=0,0009203$; or $0,0009812$; or $0,0011793$; or $0,0010142$; or $0,0016986$; or $0,0017368$; or $0,0017470$. Also $s's'E \times O^2 - s's'F = 0,2665109$; or $0,3426650$; or $0,3783127$; or $0,5413670$. $s's'F - s's'E \times O^2 = 0,2622636$; or $0,3381362$; or $0,3728667$; or $0,5366855$.

Also, at the equator, log. $t_A = 10,3562514$; or $10,3561943$; or $10,3561372$.

And the ratio of the greater axis to the lesser will be found to be as 1 to $0,9919994$; or to $0,99337$; or to $0,9927763$; or to $0,9945213$; or to $0,9954025$; or to $0,9952717$; or to $0,9951407$.

II. Putting E for $49^{\circ} 22'$, and F for each of the following. Then $\log. o$ will be $= 0,0000609$; or $0,0002589$; or $0,0000939$; or $0,0007782$; or $0,0008165$; or $0,0008267$.

And the ratio of the greater axis to the lesser will be found to be as 1 to $0,9981542$; or to $0,9946330$; or to $0,9992120$; or to $0,9968662$; or to $0,9967689$; or to $0,9966710$.

III. Putting E for 45° , and F for each of the following. Then $\log. o$ will be $= 0,0001980$; or $0,0000330$; or $0,0007173$; or $0,0007556$; or $0,0007658$.

And the ratio of the greater axis to the lesser will be found to be as 1 to $0,9870030$; or to $0,9996164$; or to $0,9967087$; or to $0,9965152$; or to $0,996467$.

IV. Putting E for 43° , and comparing it with the equatorial measures (for I do not compare it with that of $33^{\circ} 18'$, because this comparison would require the Earth to be oblong, contrary to the tenor of the other observations,) and it will be found, that the ratio of the greater axis to the lesser is as 1 to $0,9974272$; or 1 to $0,9972334$; or 1 to $0,9971849$.

V. Putting E for $33^{\circ} 18'$, and comparing it with the equatorial measures, it will be found, that the ratio of the greater axis to the lesser is as 1 to $0,9949364$; or 1 to $0,9946205$; or 1 to $0,9945677$.

The arithmetical means of the several comparisons are $0,9940688$; $0,9946736$; $0,9952611$; $0,9972818$; $0,9947082$.

And the mean of all of them is $0,9951989$.

130.

REMARK.

The latitudes of $49^{\circ} 22'$ and of 45° fall within the meridian line drawn through France, the measures of which formerly taken have been re-examined, and corrected, since the northern and southern expeditions. If we compare these only with those two different measurements, that by Mr. Maupertuis and his associates in the north, and that by Bouguer at the equator, the ratio of the greater axis to the lesser will be reduced to these six, viz. as 1 to $0,9919994$; or 1 to $0,99337$; or 1 to $0,9952717$; or 1 to $0,9981542$; or 1 to $0,9967698$; or 1 to $0,9965152$.

The arithmetical mean of these ratios, viz. of 1 to $0,9953467$, may be taken for the ratio of the greater axis to the lesser; which is as 230 to 228,92974, or very near the ratio assigned by Newton.

131. *The proportion of the axes being given, to find their magnitude from a measurement at the equator.*

The circular arch equal to the radius is $57,29578$ degrees; therefore this number multiplying the measure at the equator, gives the radius of curvature there; which is half the *latus rectum* appertaining to the greater axis; and this is to half the lesser axis in the ratio of the lesser axis to the greater: hence first the lesser axis, and then the greater will be made known.

Thus, if the greater axis is to the lesser as 1 to $0,9953467$, and the measure at the equator 56753 toises, as Bouguer has stated it, then the lesser semi-axis will be 3266910 toises, and the greater 3282183 .

132. To

132. *To find the same from a measurement taken in any latitude.*

If M represents the measure in a latitude denoted by E, and N the measure at the equator, N may be found as follows.

By Corollary III. Problem I. If an angle A be found, such that its tangent may be $= \frac{\text{lesser axis}}{\text{greater axis}} \times t, E$; N, the measure at the equator will

$$\text{be} = M \times \text{cube} \frac{s, E}{s, A}.$$

And hence the axes may be known as above.

From the measures in the latitudes $66^{\circ} 20'$; $49^{\circ} 22'$; 45° ; and at the equator, six ratios between the axes were found (130); now each ratio being compared with both of its respective latitudes and measures, will give nine values of the axes. Thus

The greater semi-axis = 3277500, or 3277484, or 3279655, or 3279702, or 3271718, or 3271779, or 3282937, or 3273007, or 3274479.

The lesser semi-axis = 3251278, or 3251263, or 3257911, or 3257958, or 3265678, or 3265704, or 3267414, or 3262430, or 3263053:

The respective means will be $\left\{ \begin{array}{l} \text{the greater semi-axis } 3276473. \\ \text{the lesser semi-axis } 3260299. \end{array} \right.$

And between these and those found at article 130, the means will be for the greater semi-axis, 3279328, and for the lesser 3263604.

And these proportioned by the mean ratio of the axis, found art. 130, will give finally, for $\left\{ \begin{array}{l} \text{the greater semi-axis } 3279328 \\ \text{the lesser semi-axis } 3264068 \end{array} \right\}$ French toises.

133. Hence the English foot being to the French, as 107 to 114; the greater semi-axis will be 3493863 English fathoms, and the lesser 3477606 English fathoms.

And an English mile consisting of 880 fathoms; the greater semi-axis will be 3970,298 miles, and the lesser 3951,824 miles.

134. Since in problem III. the excess of the arch of latitude, to the radius $\frac{bb \times 4aa + 3cc}{4a^3}$, above the corresponding elliptic arch, is to $\frac{3bbcc}{8a^3}$

as the sine of twice the latitude to radius; and the number of minutes in any arch is equal to the length of that arch multiplied by $3437\frac{1}{2}$ (the number of minutes in an arch equal to the radius) and divided by the radius of that arch, the number of minutes of the circle, the radius of

which is $\frac{bb \times 4aa + 3cc}{4a^3}$, contained in this excess, will be $\frac{3bbcc}{8a^3} \times 3437\frac{1}{2}$

divided by this radius, that is, to $\frac{\frac{3cc}{4aa + 3cc}}{\frac{bb \times 4aa + 3cc}{4a^3}} \times 3437\frac{1}{2}$, as the sine of twice the latitude to radius. But a being equal to 230, and $b = 228,92974$,

$\frac{\frac{3cc}{4aa + 3cc}}{\frac{bb \times 4aa + 3cc}{4a^3}} \times 3437\frac{1}{2}$ will be equal to 11,887 (nearly 12.)

Therefore the excess of the minutes of latitude above the minutes contained in the arch equal to AD of the circle, the semi-diameter of which is $\frac{bb \times 4aa + 3cc}{4a^3}$, will be to 11,887, as the sine of twice the latitude to radius.

And thus will the arch AD be assigned, as measured by a log-line adjusted to the divisions of the elliptical quadrant into 60 times 90 parts, according to the length assigned to this quadrant in the corollary annexed to Problem III.

135. This number to be deducted may also be found nearly enough by the traverse tables, thus: (VII. 66, 67.)

Among the courses seek the double of the given latitude, when under 45° , or the double of the complement of the latitude, when above 45° , and against 12 in the column of distances take the corresponding departure for the number to be deducted.

In an oblique course, the distance run between any two latitudes will be to the arch of the meridian contained within those latitudes, as radius to the co-sine of the course.

136. In the next place, in regard to the ship's change in longitude on an oblique course, the difference between the meridional parts for the sphere and spheroid (by Problem IV.) is to $\frac{AC^2 - CP^2}{AC^2} \times 3437\frac{3}{4}$, as the sine of the latitude the ship arrives at from the equator, to radius.

Therefore, when the equatorial diameter of the earth is to the polar diameter, as 230 to 228,92974, the difference of the spheroidal meridional parts from those of the sphere will be to 31,919, as the sine of the latitude to radius. But by the constitution of the meridian line, the meridional parts express the change of longitude made by a ship, whether on the sphere or spheroid, on the rhumb of 45° .

And the change of longitude on this rhumb is to the change of longitude on any other rhumb, as the tangent of 45° , that is, the radius, to the tangent of that other rhumb.

137. Moreover, this reduction of the meridional parts from the sphere to the spheroid may be taken nearly from the traverse tables, thus:

With the given latitude among the courses, and against 32 in the column of distances, take the corresponding departure for the reduction.

138. In a course due east or west at any latitude, the ratio of the radius of that parallel run upon in the spheroid, to the semi-diameter of the Earth's equator, is found by Problem II. And any distance run upon that parallel, measured by the log, being reduced to minutes of the Earth's equator; those minutes will be to the change of longitude in minutes, as the radius of that parallel to the semi-diameter of the equator.

The preceding precepts will be sufficiently illustrated by the following examples.

139. EXAM. I. *Let it be proposed to find the distance a ship shall run upon the supposed elliptical meridian, in increasing her latitude from 42° to 68° degrees.*

According to article 134, the log-line being adjusted to a sphere, the semi-diameter of which is $\frac{bb \times 4aa + 3cc}{4a^3}$, the reduction from this sphere to the spheroidal earth will be to 11,887, as the sine of twice the latitude to radius, and the calculation will proceed thus:

For

<i>For the lat. 42°.</i>			<i>For the lat. 68°.</i>		
As rad.		10,00000	As rad.		10,00000
To s, 84° (2 × 42°)		9 99761	To s, 136° (2 × 68°)		9,84177
So	11,887	1,07507	So	11,887	1,07507
To the reduction	11,822	1,07268	To the reduction	8,257	0,91684
Minutes in 42°	=	2520,000	Minutes in 68°	=	4080,000
reduction	=	11,822	reduction	=	8,257
The elliptic arc for 42°	=	2508,178	The elliptic arc for 68°	=	4071,743

The lesser number deducted from the greater gives 1563,564 for the divisions of the log-line adjusted to the measurement of the elliptic meridian, which are contained between the latitudes of 42° and 68° on the same side of the equator.

Moreover, in the traverse table, under twice 42°, over-against the number 12 in the column of distance, stands in the column of departure, the number 12 for the first correction; and under twice 90°—68°, that is, 44°, stands the number 8 for the second.

140. EXAM. II. *Let it be proposed to find the course and distance from the Lizard, in the latitude of 49° 57' N. to Barbadoes, in the latitude of 13° N., the difference of longitude being 54° 36' = 3276'.*

For the arch of the meridian, the reduction for the greater latitude is 11,71, and for the lesser 5,22. Therefore the latitudes reduced are 2985,29, and 774,78, the difference is 2210,51, which is the measure of the elliptic arch between the two latitudes in the measures of the log-line, adjusted as above.

In the next place the meridional parts are thus calculated.

<i>For the latitude 49° 57'.</i>			<i>For the latitude 13° 0'.</i>		
As rad.		10,00000	As rad.		10,00000
To s, lat.	= 49 57'	9,88393	To s, lat.	13° 0'	9,35209
So	31,919	1,50405	So	31,919	1,50405
To the reduction	24,43	1,38798	To the reduction	7,18	0,85614
For the latitude of 49° 57'			For the latitude of 13°		
The spheric ^l . mer. parts	=	3469,80	The spheric ^l . mer. parts	=	786,80
reduction	=	24,43	reduction	=	7,18
The spheroid ^l . mer. parts	=	3445,37	The spheroid ^l . mer. parts	=	779,62

Also under each of the latitudes, in the traverse table the same reductions will be found nearly in the columns of departure over-against the number 32 in the column of distance.

The difference of the numbers 3445,37 and 779,62, being 2665,75, is the meridional parts in the spheroid for the difference of the latitudes. And the meridional diff. lat. in the sphere is 2683,0.

Hence for the course and distance.

In the spheroid.			But in the sphere		
Diff. long. =	3276,0	3,51534	Diff. long. =	3276,0	3,51534
Mer. parts =	2665,75	3,42582	Mer. diff. lat. =	2683,0	3,42862
Tan. course =	50° 51' 50"	10,08952	Tang. course =	50° 41' 0"	10,08672

For the distance.

In the spheroid.			In the sphere.		
Arch of the mer. in min. or miles of the log. line.	2210,51	3,34449	49° 57' - 13° 0' = 36° 57' = 2217 min.		
Co-f. of the course 50° 51' 50"	980014		Proper diff. lat. = 2217	3,34577	
			Co-f. of the course = 50° 41'	9,80182	
Distance in the measures of the log. }	3502	3,54435	Dist. in min. of the sphere }	3499	3,54395

141 EXAM. III. To find the distance of Cape Henry in lat. 37° N. and long. 76° 23' W. from St. Mary's, nearly in the same latitude, with longitude 22° 56' W.

The difference of longitude 53° 27' = 3207 m.

In the spheroid.			In the sphere.		
CA (fig. Prob. II.)	0,00203	Co-f.	9,90307	Co-f. 37°	9,90235
CP		Diff. long.	3,50610	Diff. long.	3,50610
Co-t. latitude	10,12289				
Co-t. A.	10,12492	2564½	3,40917	2561¼	3,40845

Thus in the spheroid the parallel in the latitude of 37° contains for 3207 minutes of longitude 2564½ minutes of the equator; and if the logarithm of $\frac{AF}{AP}$ in the figure of Prob. II. (=0,00101) had been farther added to the logarithm of 2564½, the sum of these logarithms would have been 3,41018, and the arch of the parallel would be found to contain 2571½ minutes, as measured by the log-line; whereas, in the sphere, this portion of the parallel contains 2561¼ minutes of the equator.

142.

REMARK.

It appears from the preceding reductions, that the course of a ship on the earth, considered as a spheroid, is so near to what it would be on a sphere, the circumference of which is equal to that of one of the elliptical meridians, that with a log-line adjusted to such a sphere, an artist may safely trust to the single rules of globular sailing in his days works, even though his account of course and distance were much more certain than it is possible for them to be. It is therefore unnecessary here to enter into the question, whether the figure of the earth is a genuine spheroid, formed by the revolution of a real ellipsis about its axis, or of some more compounded figure, as Mr. Bouguer, who has discussed this point at large, contends, presuming on the precise accuracy of the several measurements.

143. A

143. A TABLE
OF
MERIDIONAL PARTS
To every DEGREE and MINUTE
OF THE
QUADRANT.

Calculated on a Supposition that the EARTH is a
perfect Sphere.

Where D. l. stands for degree of lat. and M. P. for meridional parts,
seek the degrees of latitude at the top or bottom, and the minutes in the
right or left hand columns; and the corresponding meridional parts
will stand right against the minutes, and in the column signed with
the degree proposed.

D. I.	0	1	2	3	4	5	6	7	8	9	D. I.
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
0	0,0	60,0	120,0	180,1	240,2	300,4	360,7	421,1	481,6	542,2	0
1	1,0	61,0	121,0	181,1	241,2	301,4	361,7	422,1	482,6	543,3	1
2	2,0	62,0	122,0	182,1	242,2	302,4	362,7	423,1	483,6	544,3	2
3	3,0	63,0	123,0	183,1	243,2	303,4	363,7	424,1	484,6	545,3	3
4	4,0	64,0	124,0	184,1	244,2	304,4	364,7	425,1	485,6	546,3	4
5	5,0	65,0	125,0	185,1	245,2	305,4	365,7	426,1	486,6	547,3	5
6	6,0	66,0	126,0	186,1	246,2	306,4	366,7	427,1	487,6	548,3	6
7	7,0	67,0	127,0	187,1	247,2	307,4	367,7	428,1	488,6	549,3	7
8	8,0	68,0	128,0	188,1	248,2	308,4	368,7	429,1	489,6	550,3	8
9	9,0	69,0	129,0	189,1	249,2	309,4	369,7	430,1	490,7	551,4	9
10	10,0	70,0	130,0	190,1	250,2	310,4	370,7	431,1	491,7	552,4	10
11	11,0	71,0	131,0	191,1	251,2	311,4	371,7	432,1	492,7	553,4	11
12	12,0	72,0	132,0	192,1	252,2	312,4	372,7	433,1	493,7	554,4	12
13	13,0	73,0	133,0	193,1	253,2	313,4	373,7	434,2	494,7	555,4	13
14	14,0	74,0	134,0	194,1	254,2	314,4	374,7	435,2	495,7	556,4	14
15	15,0	75,0	135,0	195,1	255,2	315,4	375,7	436,2	496,7	557,4	15
16	16,0	76,0	136,0	196,1	256,2	316,4	376,8	437,2	497,7	558,4	16
17	17,0	77,0	137,0	197,1	257,2	317,5	377,8	438,2	498,7	559,4	17
18	18,0	78,0	138,0	198,1	258,2	318,5	378,8	439,2	499,8	560,5	18
19	19,0	79,0	139,0	199,1	259,2	319,5	379,8	440,2	500,8	561,5	19
20	20,0	80,0	140,0	200,1	260,2	320,5	380,8	441,2	501,8	562,5	20
21	21,0	81,0	141,0	201,1	261,3	321,5	381,8	442,2	502,8	563,5	21
22	22,0	82,0	142,0	202,1	262,3	322,5	382,8	443,2	503,8	564,5	22
23	23,0	83,0	143,0	203,1	263,3	323,5	383,8	444,2	504,8	565,5	23
24	24,0	84,0	144,0	204,1	264,3	324,5	384,8	445,2	505,8	566,6	24
25	25,0	85,0	145,0	205,1	265,3	325,5	385,8	446,3	506,8	567,6	25
26	26,0	86,0	146,0	206,1	266,3	326,5	386,8	447,3	507,8	568,6	26
27	27,0	87,0	147,0	207,1	267,3	327,5	387,8	448,3	508,9	569,6	27
28	28,0	88,0	148,0	208,1	268,3	328,5	388,8	449,3	509,9	570,6	28
29	29,0	89,0	149,0	209,1	269,3	329,5	389,8	450,3	510,9	571,6	29
30	30,0	90,0	150,0	210,1	270,3	330,5	390,8	451,3	511,9	572,6	30
31	31,0	91,0	151,0	211,1	271,3	331,5	391,8	452,3	512,9	573,7	31
32	32,0	92,0	152,0	212,1	272,3	332,5	392,9	453,3	513,9	574,7	32
33	33,0	93,0	153,1	213,1	273,3	333,5	393,9	454,3	514,9	575,7	33
34	34,0	94,0	154,1	214,1	274,3	334,5	394,9	455,3	515,9	576,7	34
35	35,0	95,0	155,1	215,1	275,3	335,5	395,9	456,3	516,9	577,7	35
36	36,0	96,0	156,1	216,1	276,3	336,5	396,9	457,3	518,0	578,7	36
37	37,0	97,0	157,1	217,1	277,3	337,5	397,9	458,4	519,0	579,7	37
38	38,0	98,0	158,1	218,1	278,3	338,5	398,9	459,4	520,0	580,8	38
39	39,0	99,0	159,1	219,1	279,3	339,6	399,9	460,4	521,0	581,8	39
40	40,0	100,0	160,1	220,2	280,3	340,6	400,9	461,4	522,0	582,8	40
41	41,0	101,0	161,1	221,2	281,3	341,6	401,9	462,4	523,0	583,8	41
42	42,0	102,0	162,1	222,2	282,3	342,6	402,9	463,4	524,0	584,8	42
43	43,0	103,0	163,1	223,2	283,3	343,6	403,9	464,4	525,0	585,8	43
44	44,0	104,0	164,1	224,2	284,3	344,6	404,9	465,4	526,0	586,8	44
45	45,0	105,0	165,1	225,2	285,3	345,6	405,9	466,4	527,1	587,9	45
46	46,0	106,0	166,1	226,2	286,3	346,6	407,0	467,4	528,1	588,9	46
47	47,0	107,0	167,1	227,2	287,3	347,6	408,0	468,4	529,1	589,9	47
48	48,0	108,0	168,1	228,2	288,3	348,6	409,0	469,5	530,1	590,9	48
49	49,0	109,0	169,1	229,2	289,3	349,6	410,0	470,5	531,1	591,9	49
50	50,0	110,0	170,1	230,2	290,3	350,6	411,0	471,5	532,1	592,9	50
51	51,0	111,0	171,1	231,2	291,3	351,6	412,0	472,5	533,1	593,9	51
52	52,0	112,0	172,1	232,2	292,4	352,6	413,0	473,5	534,1	595,0	52
53	53,0	113,0	173,1	233,2	293,4	353,6	414,0	474,5	535,1	596,0	53
54	54,0	114,0	174,1	234,2	294,4	354,6	415,0	475,5	536,2	597,0	54
55	55,0	115,0	175,1	235,2	295,4	355,6	416,0	476,5	537,2	598,0	55
56	56,0	116,0	176,1	236,2	296,4	356,6	417,0	477,5	538,2	599,0	56
57	57,0	117,0	177,1	237,2	297,4	357,6	418,0	478,5	539,2	600,0	57
58	58,0	118,0	178,1	238,2	298,4	358,6	419,0	479,5	540,2	601,0	58
59	59,0	119,0	179,1	239,2	299,4	359,6	420,0	480,5	541,2	602,1	59
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
D. I.	0	1	2	3	4	5	6	7	8	9	D. I.

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D. l.	10	11	12	13	14	15	16	17	18	19	D. l.
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
0	603,1	664,1	725,3	786,8	848,5	910,5	972,8	1035,3	1098,2	1161,5	0
1	604,1	665,1	726,4	787,8	849,5	911,5	973,8	1036,3	1099,3	1162,5	1
2	605,1	666,1	727,4	788,8	850,5	912,6	974,8	1037,4	1100,3	1163,6	2
3	606,1	667,1	728,4	789,9	851,6	913,6	975,9	1038,4	1101,4	1164,7	3
4	607,1	668,1	729,4	790,9	852,6	914,6	976,9	1039,5	1102,4	1165,7	4
5	608,2	669,2	730,5	791,9	853,6	915,7	978,0	1040,5	1103,5	1166,8	5
6	609,2	670,2	731,5	792,9	854,7	916,7	979,0	1041,6	1104,5	1167,8	6
7	610,2	671,2	732,5	794,0	855,7	917,7	980,0	1042,6	1105,6	1168,9	7
8	611,2	672,2	733,5	795,0	856,7	918,8	981,1	1043,7	1106,6	1170,0	8
9	612,2	673,2	734,5	796,0	857,8	919,8	982,1	1044,7	1107,7	1171,0	9
10	613,2	674,3	735,6	797,0	858,8	920,8	983,2	1045,8	1108,7	1172,1	10
11	614,2	675,3	736,6	798,1	859,8	921,9	984,2	1046,8	1109,8	1173,1	11
12	615,3	676,3	737,6	799,1	860,9	922,9	985,2	1047,9	1110,8	1174,2	12
13	616,3	677,3	738,6	800,2	861,9	923,9	986,3	1048,9	1111,9	1175,2	13
14	617,3	678,4	739,6	801,2	862,9	925,0	987,3	1049,9	1112,9	1176,3	14
15	618,3	679,4	740,7	802,2	864,0	926,0	988,4	1051,0	1114,0	1177,4	15
16	619,3	680,4	741,7	803,2	865,0	927,0	989,4	1052,0	1115,0	1178,4	16
17	620,3	681,4	742,7	804,2	866,0	928,1	990,4	1053,1	1116,1	1179,5	17
18	621,3	682,4	743,7	805,3	867,1	929,1	991,5	1054,1	1117,1	1180,5	18
19	622,4	683,4	744,8	806,3	868,1	930,1	992,5	1055,2	1118,2	1181,6	19
20	623,4	684,5	745,8	807,3	869,1	931,2	993,6	1056,2	1119,2	1182,7	20
21	624,4	685,5	746,8	808,4	870,1	932,2	994,6	1057,3	1120,3	1183,7	21
22	625,4	686,5	747,8	809,4	871,2	933,2	995,6	1058,3	1121,3	1184,8	22
23	626,4	687,5	748,9	810,4	872,2	934,3	996,7	1059,4	1122,4	1185,8	23
24	627,4	688,5	749,9	811,4	873,2	935,3	997,7	1060,4	1123,4	1186,9	24
25	628,5	689,6	750,9	812,5	874,3	936,3	998,8	1061,4	1124,5	1188,0	25
26	629,5	690,6	751,9	813,5	875,3	937,4	999,8	1062,5	1125,5	1189,0	26
27	630,5	691,6	753,0	814,5	876,3	938,4	1000,8	1063,5	1126,6	1190,1	27
28	631,5	692,6	754,0	815,5	877,4	939,4	1001,9	1064,6	1127,6	1191,1	28
29	632,5	693,6	755,0	816,6	878,4	940,5	1002,9	1065,6	1128,7	1192,2	29
30	633,5	694,7	756,0	817,6	879,4	941,5	1004,0	1066,7	1129,7	1193,2	30
31	634,6	695,7	757,1	818,6	880,5	942,5	1005,0	1067,7	1130,8	1194,3	31
32	635,6	696,7	758,1	819,6	881,5	943,5	1006,1	1068,8	1131,8	1195,4	32
33	636,6	697,7	759,1	820,7	882,5	944,6	1007,1	1069,8	1132,9	1196,4	33
34	637,6	698,7	760,1	821,7	883,6	945,6	1008,1	1070,9	1134,0	1197,5	34
35	638,6	699,8	761,1	822,7	884,6	946,7	1009,2	1072,0	1135,1	1198,5	35
36	639,6	700,8	762,2	823,8	885,6	947,7	1010,2	1073,0	1136,1	1199,6	36
37	640,7	701,8	763,2	824,8	886,7	948,7	1011,3	1074,1	1137,2	1200,7	37
38	641,7	702,8	764,2	825,8	887,7	949,8	1012,3	1075,1	1138,2	1201,7	38
39	642,7	703,8	765,2	826,8	888,7	950,8	1013,4	1076,2	1139,3	1202,8	39
40	643,7	704,9	766,3	827,9	889,8	951,9	1014,4	1077,2	1140,3	1203,9	40
41	644,7	705,9	767,3	828,9	890,8	952,9	1015,4	1078,3	1141,4	1204,9	41
42	645,8	706,9	768,3	829,9	891,8	953,9	1016,5	1079,3	1142,4	1206,0	42
43	646,8	707,9	769,3	831,0	892,9	955,0	1017,5	1080,4	1143,5	1207,1	43
44	647,8	709,0	770,4	832,0	893,9	956,0	1018,6	1081,4	1144,6	1208,1	44
45	648,8	710,0	771,4	833,0	894,9	957,1	1019,6	1082,5	1145,6	1209,2	45
46	649,8	711,0	772,4	834,1	896,0	958,1	1020,6	1083,5	1146,7	1210,2	46
47	650,8	712,0	773,4	835,1	897,0	959,2	1021,7	1084,6	1147,7	1211,3	47
48	651,9	713,0	774,5	836,1	898,0	960,2	1022,7	1085,6	1148,8	1212,4	48
49	652,9	714,1	775,5	837,2	899,1	961,3	1023,8	1086,7	1149,8	1213,4	49
50	653,9	715,1	776,5	838,2	900,1	962,3	1024,8	1087,7	1150,9	1214,5	50
51	654,9	716,1	777,5	839,2	901,1	963,4	1025,9	1088,8	1152,0	1215,5	51
52	655,9	717,1	778,6	840,2	902,2	964,4	1026,9	1089,8	1153,0	1216,6	52
53	657,0	718,2	779,6	841,3	903,2	965,5	1028,0	1090,9	1154,1	1217,7	53
54	658,0	719,2	780,6	842,3	904,3	966,5	1029,0	1091,9	1155,1	1218,7	54
55	659,0	720,2	781,7	843,4	905,3	967,6	1030,1	1093,0	1156,2	1219,8	55
56	660,0	721,2	782,7	844,4	906,3	968,6	1031,1	1094,0	1157,2	1220,9	56
57	661,0	722,3	783,7	845,4	907,4	969,6	1032,2	1095,1	1158,3	1221,9	57
58	662,1	723,3	784,7	846,5	908,4	970,7	1033,2	1096,1	1159,4	1223,0	58
59	663,1	724,3	785,8	847,5	909,4	971,7	1034,3	1097,2	1160,4	1224,1	59
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
D. l.	10	11	12	13	14	15	16	17	18	19	D. l.

D. l.	20	21	22	23	24	25	26	27	28	29	D. l.
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
0	1225,1	1289,2	1353,7	1418,6	1484,1	1550,0	1616,5	1683,5	1751,2	1819,5	0
1	1226,2	1290,3	1354,8	1419,7	1485,2	1551,1	1617,6	1684,6	1752,3	1820,6	1
2	1227,3	1291,3	1355,8	1420,8	1486,3	1552,2	1618,7	1685,8	1753,4	1821,7	2
3	1228,3	1292,4	1356,9	1421,9	1487,3	1553,3	1619,8	1686,9	1754,6	1822,9	3
4	1229,4	1293,5	1358,0	1423,0	1488,4	1554,4	1620,9	1688,0	1755,7	1824,0	4
5	1230,4	1294,5	1359,0	1424,1	1489,5	1555,5	1622,0	1689,1	1756,8	1825,2	5
6	1231,5	1295,6	1360,2	1425,1	1490,6	1556,6	1623,2	1690,3	1758,0	1826,3	6
7	1232,6	1296,7	1361,2	1426,2	1491,7	1557,7	1624,3	1691,4	1759,1	1827,5	7
8	1233,6	1297,8	1362,3	1427,3	1492,8	1558,8	1625,4	1692,5	1760,2	1828,6	8
9	1234,7	1298,8	1363,4	1428,4	1493,9	1559,9	1626,5	1693,6	1761,4	1829,7	9
10	1235,8	1299,9	1364,5	1429,5	1495,0	1561,0	1627,6	1694,8	1762,5	1830,9	10
11	1236,8	1301,0	1365,6	1430,6	1496,1	1562,1	1628,7	1695,9	1763,6	1832,0	11
12	1237,9	1302,0	1366,6	1431,7	1497,2	1563,2	1629,8	1697,0	1764,8	1833,2	12
13	1239,0	1303,1	1367,7	1432,8	1498,3	1564,3	1631,0	1698,1	1765,9	1834,3	13
14	1240,0	1304,2	1368,8	1433,9	1499,4	1565,4	1632,1	1699,3	1767,0	1835,5	14
15	1241,1	1305,3	1369,9	1434,9	1500,5	1566,5	1633,2	1700,4	1768,2	1836,6	15
16	1242,2	1306,3	1370,9	1436,0	1501,6	1567,6	1634,3	1701,5	1769,3	1837,8	16
17	1243,2	1307,4	1372,0	1437,1	1502,7	1568,7	1635,4	1702,6	1770,5	1838,9	17
18	1244,3	1308,5	1373,1	1438,2	1503,8	1569,8	1636,5	1703,8	1771,6	1840,1	18
19	1245,4	1309,6	1374,2	1439,3	1504,9	1571,0	1637,7	1704,9	1772,7	1841,2	19
20	1246,4	1310,6	1375,3	1440,4	1506,0	1572,1	1638,8	1706,0	1773,9	1842,4	20
21	1247,5	1311,7	1376,4	1441,5	1507,1	1573,2	1639,9	1707,1	1775,0	1843,5	21
22	1248,6	1312,8	1377,4	1442,6	1508,2	1574,3	1641,0	1708,3	1776,1	1844,6	22
23	1249,6	1313,8	1378,5	1443,7	1509,3	1575,4	1642,1	1709,4	1777,2	1845,8	23
24	1250,7	1314,9	1379,6	1444,8	1510,4	1576,5	1643,2	1710,5	1778,4	1846,9	24
25	1251,8	1316,0	1380,7	1445,8	1511,5	1577,6	1644,3	1711,6	1779,5	1848,1	25
26	1252,8	1317,1	1381,8	1446,9	1512,6	1578,7	1645,5	1712,8	1780,6	1849,2	26
27	1253,9	1318,1	1382,8	1448,0	1513,7	1579,8	1646,6	1713,9	1781,8	1850,4	27
28	1255,0	1319,2	1383,9	1449,1	1514,8	1580,9	1647,7	1715,0	1783,0	1851,5	28
29	1256,0	1320,3	1385,0	1450,2	1515,9	1582,0	1648,8	1716,1	1784,1	1852,7	29
30	1257,1	1321,4	1386,1	1451,3	1517,0	1583,2	1649,9	1717,3	1785,2	1853,8	30
31	1258,2	1322,5	1387,2	1452,4	1518,1	1584,3	1651,0	1718,4	1786,4	1855,0	31
32	1259,2	1323,5	1388,3	1453,5	1519,2	1585,4	1652,2	1719,5	1787,5	1856,1	32
33	1260,3	1324,6	1389,4	1454,6	1520,3	1586,5	1653,3	1720,7	1788,6	1857,2	33
34	1261,4	1325,7	1390,4	1455,6	1521,4	1587,6	1654,4	1721,8	1789,8	1858,4	34
35	1262,4	1326,7	1391,5	1456,7	1522,5	1588,7	1655,5	1722,9	1790,9	1859,6	35
36	1263,5	1327,8	1392,6	1457,8	1523,6	1589,8	1656,6	1724,0	1792,1	1860,7	36
37	1264,6	1328,9	1393,7	1458,9	1524,7	1590,9	1657,8	1725,2	1793,2	1861,9	37
38	1265,6	1330,0	1394,8	1460,0	1525,8	1592,0	1658,9	1726,3	1794,3	1863,0	38
39	1266,7	1331,0	1395,8	1461,1	1526,9	1593,2	1660,0	1727,4	1795,5	1864,2	39
40	1267,8	1332,1	1396,9	1462,2	1528,0	1594,3	1661,1	1728,6	1796,6	1865,3	40
41	1268,8	1333,2	1398,0	1463,3	1529,1	1595,4	1662,2	1729,7	1797,8	1866,5	41
42	1269,9	1334,3	1399,1	1464,4	1530,2	1596,5	1663,4	1730,8	1798,9	1867,6	42
43	1271,0	1335,3	1400,2	1465,5	1531,3	1597,6	1664,5	1731,9	1800,0	1868,8	43
44	1272,1	1336,4	1401,3	1466,6	1532,4	1598,7	1665,6	1733,1	1801,2	1869,9	44
45	1273,1	1337,5	1402,4	1467,7	1533,5	1599,8	1666,7	1734,2	1802,3	1871,1	45
46	1274,2	1338,6	1403,4	1468,8	1534,6	1600,9	1667,8	1735,3	1803,5	1872,2	46
47	1275,3	1339,7	1404,5	1469,8	1535,7	1602,0	1669,0	1736,5	1804,6	1873,4	47
48	1276,3	1340,7	1405,6	1470,9	1536,8	1603,1	1670,1	1737,6	1805,7	1874,5	48
49	1277,4	1341,8	1406,7	1472,0	1537,9	1604,3	1671,2	1738,7	1806,9	1875,7	49
50	1278,5	1342,9	1407,8	1473,1	1539,0	1605,4	1672,3	1739,9	1808,0	1876,8	50
51	1279,5	1344,0	1408,8	1474,2	1540,1	1606,5	1673,4	1741,0	1809,2	1878,0	51
52	1280,6	1345,1	1409,9	1475,3	1541,2	1607,6	1674,5	1742,1	1810,3	1879,2	52
53	1281,7	1346,1	1411,0	1476,4	1542,3	1608,7	1675,7	1743,2	1811,4	1880,3	53
54	1282,8	1347,2	1412,1	1477,5	1543,4	1609,8	1676,8	1744,4	1812,6	1881,5	54
55	1283,8	1348,3	1413,2	1478,6	1544,5	1610,9	1678,0	1745,5	1813,7	1882,6	55
56	1284,9	1349,4	1414,3	1479,7	1545,6	1612,0	1679,1	1746,6	1814,9	1883,8	56
57	1286,0	1350,4	1415,4	1480,8	1546,7	1613,1	1680,2	1747,8	1816,0	1884,9	57
58	1287,0	1351,5	1416,5	1481,9	1547,8	1614,2	1681,3	1748,9	1817,2	1886,1	58
59	1288,1	1352,6	1417,6	1483,0	1548,9	1615,4	1682,4	1750,0	1818,3	1887,2	59
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
D. l.	20	21	22	23	24	25	26	27	28	29	D. l.

MERIDIONAL PARTS. 143. 219

D. I.	30	31	32	33	34	35	36	37	38	39	D. I.
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
0	1888,4	1958,0	2028,4	2099,6	2171,5	2244,3	2318,0	2392,7	2468,3	2545,0	0
1	1889,5	1959,2	2029,6	2100,7	2172,7	2245,5	2319,3	2393,9	2469,6	2546,2	1
2	1890,7	1960,4	2030,7	2101,9	2173,9	2246,8	2320,5	2395,2	2470,8	2547,5	2
3	1891,9	1961,6	2031,9	2103,1	2175,1	2248,0	2321,7	2396,4	2472,1	2548,8	3
4	1893,0	1962,7	2033,1	2104,3	2176,3	2249,2	2323,0	2397,7	2473,4	2550,1	4
5	1894,1	1963,9	2034,3	2105,5	2177,5	2250,4	2324,2	2398,9	2474,6	2551,4	5
6	1895,3	1965,0	2035,5	2106,7	2178,7	2251,6	2325,4	2400,2	2475,9	2552,7	6
7	1896,5	1966,2	2036,7	2107,9	2180,0	2252,9	2326,7	2401,4	2477,1	2554,0	7
8	1897,6	1967,4	2037,8	2109,1	2181,2	2254,1	2327,9	2402,7	2478,5	2555,3	8
9	1898,8	1968,5	2039,0	2110,3	2182,4	2255,3	2329,2	2403,9	2479,7	2556,6	9
10	1899,9	1969,7	2040,2	2111,5	2183,6	2256,5	2330,4	2405,2	2481,0	2557,8	10
11	1901,1	1970,9	2041,4	2112,7	2184,8	2257,8	2331,6	2406,4	2482,3	2559,1	11
12	1902,3	1972,0	2042,6	2113,9	2186,0	2259,0	2332,9	2407,7	2483,5	2560,4	12
13	1903,4	1973,2	2043,8	2115,1	2187,2	2260,2	2334,1	2409,0	2484,8	2561,7	13
14	1904,6	1974,4	2044,9	2116,3	2188,4	2261,4	2335,3	2410,2	2486,1	2563,0	14
15	1905,7	1975,6	2046,1	2117,5	2189,6	2262,7	2336,6	2411,5	2487,4	2564,3	15
16	1906,9	1976,8	2047,3	2118,7	2190,8	2263,9	2337,8	2412,7	2488,6	2565,6	16
17	1908,1	1977,9	2048,5	2119,8	2192,0	2265,1	2339,0	2414,0	2489,9	2566,9	17
18	1909,2	1979,1	2049,7	2121,0	2193,3	2266,3	2340,3	2415,2	2491,2	2568,2	18
19	1910,4	1980,3	2050,8	2122,2	2194,5	2267,6	2341,5	2416,5	2492,5	2569,5	19
20	1911,5	1981,4	2052,0	2123,4	2195,7	2268,8	2342,8	2417,8	2493,7	2570,7	20
21	1912,7	1982,6	2053,2	2124,6	2196,9	2270,0	2344,0	2419,0	2495,0	2572,0	21
22	1913,8	1983,7	2054,4	2125,8	2198,1	2271,2	2345,3	2420,3	2496,3	2573,3	22
23	1915,0	1984,9	2055,6	2127,0	2199,3	2272,5	2346,5	2421,5	2497,6	2574,6	23
24	1916,2	1986,1	2056,8	2128,2	2200,5	2273,7	2347,8	2422,8	2498,8	2575,9	24
25	1917,3	1987,3	2058,0	2129,4	2201,7	2274,9	2349,0	2424,0	2500,1	2577,2	25
26	1918,5	1988,4	2059,1	2130,6	2203,0	2276,1	2350,2	2425,3	2501,4	2578,5	26
27	1919,6	1989,6	2060,3	2131,8	2204,2	2277,4	2351,5	2426,5	2502,7	2579,7	27
28	1920,8	1990,8	2061,5	2133,0	2205,4	2278,6	2352,7	2427,8	2503,9	2581,1	28
29	1921,9	1992,0	2062,7	2134,2	2206,6	2279,8	2354,0	2429,1	2505,2	2582,4	29
30	1923,1	1993,1	2063,9	2135,4	2207,8	2281,0	2355,2	2430,3	2506,5	2583,7	30
31	1924,3	1994,3	2065,1	2136,6	2209,0	2282,3	2356,5	2431,6	2507,8	2585,0	31
32	1925,4	1995,5	2066,2	2137,8	2210,2	2283,5	2357,7	2432,9	2509,0	2586,3	32
33	1926,6	1996,6	2067,4	2139,0	2211,4	2284,7	2358,9	2434,1	2510,3	2587,6	33
34	1927,8	1997,8	2068,6	2140,2	2212,7	2286,0	2360,2	2435,4	2511,6	2588,9	34
35	1928,9	1999,0	2069,8	2141,4	2213,9	2287,2	2361,4	2436,7	2512,9	2590,2	35
36	1930,1	2000,2	2071,0	2142,6	2215,1	2288,4	2362,7	2437,9	2514,2	2591,5	36
37	1931,3	2001,3	2072,2	2143,8	2216,3	2289,7	2363,9	2439,2	2515,4	2592,8	37
38	1932,4	2002,5	2073,4	2145,0	2217,5	2290,9	2365,2	2440,4	2516,7	2594,1	38
39	1933,6	2003,7	2074,6	2146,2	2218,7	2292,1	2366,4	2441,7	2518,0	2595,4	39
40	1934,7	2004,9	2075,7	2147,4	2219,9	2293,3	2367,7	2443,0	2519,3	2596,7	40
41	1935,9	2006,0	2076,9	2148,6	2221,2	2294,6	2368,9	2444,2	2520,6	2598,0	41
42	1937,1	2007,2	2078,1	2149,8	2222,4	2295,8	2370,2	2445,5	2521,8	2599,3	42
43	1938,2	2008,4	2079,3	2151,0	2223,6	2297,0	2371,4	2446,8	2523,1	2600,6	43
44	1939,4	2009,6	2080,5	2152,2	2224,8	2298,3	2372,7	2448,0	2524,4	2601,9	44
45	1940,5	2010,7	2081,7	2153,4	2226,0	2299,5	2373,9	2449,3	2525,7	2603,2	45
46	1941,7	2011,9	2082,9	2154,6	2227,2	2300,7	2375,2	2450,6	2527,0	2604,5	46
47	1942,9	2013,1	2084,1	2155,8	2228,5	2302,0	2376,4	2451,8	2528,3	2605,8	47
48	1944,0	2014,3	2085,3	2157,0	2229,7	2303,2	2377,7	2453,1	2529,5	2607,1	48
49	1945,2	2015,4	2086,5	2158,2	2230,9	2304,4	2378,9	2454,3	2530,8	2608,4	49
50	1946,4	2016,6	2087,7	2159,4	2232,1	2305,7	2380,1	2455,6	2532,1	2609,7	50
51	1947,5	2017,8	2088,9	2160,7	2233,3	2306,9	2381,4	2456,9	2533,4	2611,0	51
52	1948,7	2019,0	2090,1	2161,9	2234,6	2308,1	2382,6	2458,1	2534,7	2612,3	52
53	1949,9	2020,2	2091,3	2163,1	2235,8	2309,4	2383,9	2459,4	2536,0	2613,6	53
54	1951,0	2021,3	2092,5	2164,3	2237,0	2310,6	2385,1	2460,7	2537,2	2614,9	54
55	1952,2	2022,5	2093,7	2165,5	2238,2	2311,8	2386,4	2461,9	2538,5	2616,2	55
56	1953,4	2023,7	2094,9	2166,7	2239,4	2313,1	2387,6	2463,2	2539,8	2617,5	56
57	1954,5	2024,9	2096,1	2167,9	2240,7	2314,3	2388,9	2464,5	2541,1	2618,8	57
58	1955,7	2026,0	2097,3	2169,1	2241,9	2315,5	2390,2	2465,8	2542,4	2620,1	58
59	1956,9	2027,2	2098,5	2170,3	2243,1	2316,7	2391,4	2467,0	2543,7	2621,4	59
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
D. I.	30	31	32	33	34	35	36	37	38	39	D. I.

D. l.	40	41	42	43	44	45	46	47	48	49	D. l.
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
0	2622,7	2701,6	2781,7	2863,1	2945,7	3030,0	3115,6	3202,8	3291,6	3382,1	0
1	2624,0	2702,9	2783,1	2864,5	2947,2	3031,4	3117,0	3204,2	3293,1	3383,6	1
2	2625,3	2704,3	2784,4	2865,8	2948,6	3032,8	3118,5	3205,7	3294,6	3385,2	2
3	2626,6	2705,6	2785,8	2867,2	2950,0	3034,2	3119,9	3207,2	3296,1	3386,7	3
4	2627,9	2706,9	2787,1	2868,5	2951,4	3035,6	3121,4	3208,6	3297,5	3388,2	4
5	2629,2	2708,3	2788,5	2870,0	2952,8	3037,0	3122,8	3210,1	3299,0	3389,7	5
6	2630,5	2709,6	2789,8	2871,3	2954,2	3038,4	3124,2	3211,6	3300,5	3391,3	6
7	2631,9	2710,9	2791,2	2872,7	2955,6	3039,8	3125,7	3213,0	3302,0	3392,8	7
8	2633,2	2712,2	2792,5	2874,1	2957,0	3041,3	3127,1	3214,5	3303,5	3394,3	8
9	2634,5	2713,6	2793,8	2875,4	2958,4	3042,7	3128,6	3216,0	3305,0	3395,9	9
10	2635,8	2714,9	2795,1	2876,8	2959,8	3044,1	3130,0	3217,4	3306,5	3397,4	10
11	2637,1	2716,2	2796,5	2878,2	2961,1	3045,5	3131,5	3218,9	3308,0	3398,9	11
12	2638,4	2717,5	2797,9	2879,5	2962,5	3047,0	3132,9	3220,4	3309,5	3400,4	12
13	2639,7	2718,9	2799,3	2880,9	2963,9	3048,4	3134,3	3221,9	3311,0	3402,0	13
14	2641,0	2720,2	2800,6	2882,3	2965,3	3049,8	3135,8	3223,3	3312,5	3403,5	14
15	2642,3	2721,5	2802,0	2883,7	2966,7	3051,2	3137,2	3224,8	3314,0	3405,0	15
16	2643,6	2722,9	2803,3	2885,0	2968,1	3052,6	3138,7	3226,3	3315,5	3406,6	16
17	2644,9	2724,2	2804,7	2886,4	2969,5	3054,1	3140,1	3227,7	3317,0	3408,1	17
18	2646,3	2725,5	2806,0	2887,8	2970,9	3055,5	3141,6	3229,2	3318,5	3409,6	18
19	2647,6	2726,9	2807,4	2889,2	2972,3	3056,9	3143,0	3230,7	3320,0	3411,2	19
20	2648,9	2728,2	2808,8	2890,5	2973,7	3058,3	3144,5	3232,2	3321,5	3412,7	20
21	2650,2	2729,5	2810,1	2891,9	2975,1	3059,7	3145,9	3233,6	3323,1	3414,2	21
22	2651,5	2730,8	2811,4	2893,3	2976,5	3061,2	3147,4	3235,1	3324,6	3415,8	22
23	2652,8	2732,2	2812,8	2894,7	2977,9	3062,6	3148,8	3236,6	3326,1	3417,3	23
24	2654,1	2733,5	2814,1	2896,0	2979,3	3064,0	3150,3	3238,1	3327,6	3418,8	24
25	2655,5	2734,8	2815,5	2897,4	2980,7	3065,4	3151,7	3239,5	3329,1	3420,4	25
26	2656,8	2736,2	2816,8	2898,8	2982,1	3066,9	3153,2	3241,0	3330,6	3421,9	26
27	2658,1	2737,5	2818,2	2900,2	2983,5	3068,3	3154,6	3242,5	3332,1	3423,5	27
28	2659,4	2738,8	2819,5	2901,5	2984,9	3069,7	3156,1	3244,0	3333,6	3425,0	28
29	2660,7	2740,2	2820,9	2902,9	2986,3	3071,1	3157,5	3245,5	3335,1	3426,5	29
30	2662,0	2741,5	2822,3	2904,3	2987,7	3072,6	3159,0	3246,9	3336,6	3428,1	30
31	2663,3	2742,9	2823,6	2905,7	2989,1	3074,0	3160,4	3248,4	3338,1	3429,6	31
32	2664,6	2744,2	2825,0	2907,1	2990,5	3075,4	3161,9	3249,9	3339,6	3431,2	32
33	2666,0	2745,5	2826,3	2908,4	2991,9	3076,9	3163,3	3251,4	3341,1	3432,7	33
34	2667,3	2746,9	2827,7	2909,7	2993,3	3078,3	3164,8	3252,9	3342,7	3434,2	34
35	2668,6	2748,2	2829,0	2911,2	2994,7	3079,7	3166,2	3254,4	3344,2	3435,8	35
36	2669,9	2749,5	2830,4	2912,6	2996,1	3081,1	3167,7	3255,8	3345,7	3437,3	36
37	2671,2	2750,9	2831,8	2914,0	2997,5	3082,6	3169,1	3257,3	3347,2	3438,9	37
38	2672,5	2752,2	2833,1	2915,3	2998,9	3084,0	3170,6	3258,8	3348,7	3440,4	38
39	2673,9	2753,5	2834,5	2916,7	3000,3	3085,4	3172,1	3260,3	3350,1	3442,0	39
40	2675,1	2754,9	2835,8	2918,1	3001,8	3086,9	3173,5	3261,8	3351,7	3443,5	40
41	2676,5	2756,2	2837,2	2919,5	3003,2	3088,3	3175,0	3263,3	3353,2	3445,0	41
42	2677,8	2757,6	2838,6	2920,9	3004,6	3089,7	3176,4	3264,7	3354,8	3446,6	42
43	2679,1	2758,9	2839,9	2922,3	3006,0	3091,2	3177,9	3266,2	3356,3	3448,1	43
44	2680,5	2760,2	2841,3	2923,6	3007,4	3092,6	3179,3	3267,7	3357,8	3449,7	44
45	2681,8	2761,5	2842,6	2925,0	3008,8	3094,0	3180,8	3269,2	3359,3	3451,2	45
46	2683,1	2762,9	2844,0	2926,4	3010,2	3095,5	3182,3	3270,7	3360,8	3452,8	46
47	2684,4	2764,3	2845,4	2927,8	3011,6	3096,9	3183,7	3272,2	3362,3	3454,3	47
48	2685,7	2765,6	2846,7	2929,2	3013,0	3098,3	3185,2	3273,7	3363,9	3455,9	48
49	2687,1	2766,9	2848,1	2930,6	3014,4	3099,8	3186,6	3275,2	3365,4	3457,4	49
50	2688,4	2768,3	2849,5	2932,0	3015,8	3101,2	3188,1	3276,6	3366,9	3459,0	50
51	2689,7	2769,6	2850,8	2933,3	3017,2	3102,6	3189,6	3278,1	3368,4	3460,5	51
52	2691,0	2771,0	2852,2	2934,7	3018,7	3104,1	3191,0	3279,6	3369,9	3462,1	52
53	2692,3	2772,3	2853,6	2936,1	3020,1	3105,6	3192,5	3281,1	3371,5	3463,6	53
54	2693,7	2773,7	2854,9	2937,5	3021,5	3107,0	3194,0	3282,6	3373,0	3465,2	54
55	2695,0	2775,0	2856,3	2938,9	3022,9	3108,4	3195,4	3284,1	3374,5	3466,7	55
56	2696,3	2776,4	2857,7	2940,3	3024,3	3109,8	3196,9	3285,6	3376,0	3468,3	56
57	2697,6	2777,7	2859,1	2941,7	3025,7	3111,2	3198,4	3287,1	3377,6	3469,8	57
58	2699,0	2779,0	2860,5	2943,1	3027,1	3112,7	3199,8	3288,6	3379,1	3471,4	58
59	2700,3	2780,4	2861,8	2944,4	3028,5	3114,1	3201,3	3290,1	3380,6	3473,0	59
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
D. l.	40	41	42	43	44	45	46	47	48	49	D. l.

D. l.	50	51	52	53	54	55	56	57	58	59	D. l.
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
0	3474,5	3568,8	3665,2	3763,8	3864,7	3968,0	4073,9	4182,6	4294,3	4409,2	0
1	3476,1	3570,4	3666,9	3765,5	3866,4	3969,7	4075,7	4184,5	4296,2	4411,1	1
2	3477,6	3572,0	3668,5	3767,1	3868,1	3971,5	4077,5	4186,3	4298,1	4413,1	2
3	3479,2	3573,6	3670,1	3768,8	3869,8	3973,2	4079,3	4188,2	4300,0	4415,0	3
4	3480,7	3575,2	3671,7	3770,4	3871,5	3975,0	4081,1	4190,0	4301,9	4417,0	4
5	3482,3	3576,8	3673,4	3772,1	3873,2	3976,7	4082,9	4191,8	4303,8	4418,9	5
6	3483,9	3578,4	3675,0	3773,8	3874,9	3978,4	4084,7	4193,7	4305,7	4420,8	6
7	3485,4	3580,0	3676,6	3775,4	3876,6	3980,2	4086,5	4195,5	4307,6	4422,8	7
8	3487,0	3581,6	3678,2	3777,1	3878,3	3982,0	4088,3	4197,4	4309,5	4424,7	8
9	3488,5	3583,2	3679,9	3778,8	3880,0	3983,7	4090,1	4199,2	4311,4	4426,7	9
10	3490,1	3584,8	3681,5	3780,4	3881,7	3985,5	4091,9	4201,1	4313,2	4428,6	10
11	3491,7	3586,4	3683,1	3782,1	3883,4	3987,2	4093,7	4202,9	4315,1	4430,6	11
12	3493,2	3588,0	3684,8	3783,8	3885,1	3989,0	4095,5	4204,7	4317,0	4432,5	12
13	3494,8	3589,5	3686,4	3785,5	3886,8	3990,7	4097,3	4206,6	4318,9	4434,5	13
14	3496,3	3591,1	3688,0	3787,1	3888,6	3992,5	4099,1	4208,4	4320,8	4436,4	14
15	3497,9	3592,7	3689,7	3788,8	3890,3	3994,2	4100,9	4210,3	4322,7	4438,4	15
16	3500,5	3594,3	3691,3	3790,5	3892,0	3996,0	4102,7	4212,1	4324,6	4440,4	16
17	3501,0	3595,9	3692,9	3792,1	3893,7	3997,7	4104,5	4214,0	4326,5	4442,3	17
18	3502,6	3597,5	3694,6	3793,8	3895,4	3999,5	4106,3	4215,8	4328,4	4444,3	18
19	3504,2	3599,1	3696,2	3795,5	3897,1	4001,3	4108,1	4217,7	4330,3	4446,2	19
20	3505,7	3600,7	3697,8	3797,2	3898,8	4003,0	4109,9	4219,5	4332,2	4448,2	20
21	3507,3	3602,3	3699,5	3798,8	3900,5	4004,8	4111,7	4221,4	4334,2	4450,2	21
22	3508,9	3603,9	3701,1	3800,5	3902,3	4006,5	4113,5	4223,2	4336,1	4452,1	22
23	3510,5	3605,5	3702,7	3802,2	3904,0	4008,3	4115,3	4225,1	4338,0	4454,1	23
24	3512,0	3607,1	3704,4	3803,9	3905,7	4010,0	4117,1	4227,0	4339,9	4456,0	24
25	3513,6	3608,7	3706,0	3805,5	3907,4	4011,8	4118,9	4228,8	4341,8	4458,0	25
26	3515,1	3610,3	3707,7	3807,2	3909,1	4013,6	4120,7	4230,7	4343,7	4460,0	26
27	3516,7	3611,9	3709,3	3808,9	3910,9	4015,3	4122,5	4232,5	4345,6	4461,9	27
28	3518,3	3613,6	3710,9	3810,6	3912,6	4017,1	4124,3	4234,4	4347,5	4463,9	28
29	3519,8	3615,2	3712,6	3812,3	3914,3	4018,9	4126,1	4236,2	4349,4	4465,9	29
30	3521,4	3616,8	3714,2	3813,9	3916,0	4020,6	4127,9	4238,1	4351,3	4467,8	30
31	3523,0	3618,4	3715,9	3815,6	3917,7	4022,4	4129,7	4240,0	4353,3	4469,8	31
32	3524,6	3620,0	3717,5	3817,3	3919,5	4024,2	4131,6	4241,8	4355,2	4471,8	32
33	3526,1	3621,6	3719,2	3819,0	3921,2	4026,0	4133,4	4243,7	4357,1	4473,8	33
34	3527,7	3623,2	3720,8	3820,7	3922,9	4027,7	4135,2	4245,6	4359,0	4475,7	34
35	3529,3	3624,8	3722,4	3822,3	3924,6	4029,5	4137,0	4247,4	4360,9	4477,7	35
36	3530,9	3626,4	3724,1	3824,0	3926,4	4031,2	4138,8	4249,3	4362,8	4479,7	36
37	3532,4	3628,0	3725,7	3825,7	3928,1	4033,0	4140,6	4251,2	4364,8	4481,7	37
38	3534,0	3629,6	3727,4	3827,4	3929,8	4034,8	4142,5	4253,0	4366,7	4483,6	38
39	3535,6	3631,3	3729,0	3829,1	3931,5	4036,6	4144,3	4254,9	4368,6	4485,6	39
40	3537,2	3632,9	3730,7	3830,8	3933,3	4038,3	4146,1	4256,8	4370,5	4487,6	40
41	3538,8	3634,5	3732,3	3832,5	3935,0	4040,1	4147,9	4258,6	4372,5	4489,6	41
42	3540,3	3636,1	3734,0	3834,2	3936,7	4041,9	4149,7	4260,5	4374,4	4491,6	42
43	3541,9	3637,7	3735,6	3835,8	3938,5	4043,6	4151,6	4262,4	4376,3	4493,5	43
44	3543,5	3639,3	3737,3	3837,5	3940,2	4045,4	4153,4	4264,3	4378,2	4495,5	44
45	3545,1	3640,9	3738,9	3839,2	3941,9	4047,2	4155,2	4266,1	4380,1	4497,5	45
46	3546,7	3642,5	3740,6	3840,9	3943,7	4049,0	4157,0	4268,0	4382,1	4499,5	46
47	3548,2	3644,2	3742,2	3842,6	3945,4	4050,8	4158,8	4269,9	4384,0	4501,5	47
48	3549,8	3645,8	3743,9	3844,3	3947,1	4052,5	4160,7	4271,8	4385,9	4503,5	48
49	3551,4	3647,4	3745,6	3846,0	3948,9	4054,3	4162,5	4273,6	4387,9	4505,5	49
50	3553,0	3649,0	3747,2	3847,7	3950,6	4056,1	4164,3	4275,5	4389,8	4507,5	50
51	3554,6	3650,6	3748,9	3849,4	3952,3	4057,9	4166,2	4277,4	4391,7	4509,4	51
52	3556,1	3652,3	3750,5	3851,1	3954,1	4059,7	4168,0	4279,3	4393,7	4511,4	52
53	3557,7	3653,9	3752,2	3852,8	3955,8	4061,4	4169,8	4281,1	4395,6	4513,4	53
54	3559,3	3655,5	3753,8	3854,5	3957,6	4063,2	4171,7	4283,0	4397,5	4515,4	54
55	3560,9	3657,1	3755,5	3856,2	3959,3	4065,0	4173,5	4284,9	4399,5	4517,4	55
56	3562,5	3658,7	3757,2	3857,9	3961,0	4066,8	4175,3	4286,8	4401,4	4519,4	56
57	3564,1	3660,4	3758,8	3859,6	3962,8	4068,6	4177,2	4288,7	4403,4	4521,4	57
58	3565,7	3662,0	3760,5	3861,3	3964,5	4070,4	4179,0	4290,6	4405,3	4523,4	58
59	3567,3	3663,6	3762,2	3863,0	3966,3	4072,1	4180,8	4292,5	4407,2	4525,4	59
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
D. l.	50	51	52	53	54	55	56	57	58	59	D. l.

D. l.	60	61	62	63	64	65	66	67	68	69	D. l.
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
0	4527,4	4649,2	4775,0	4905,0	5039,4	5178,8	5323,6	5474,0	5630,9	5794,6	0
1	4529,4	4651,3	4777,1	4907,2	5041,7	5181,2	5326,0	5476,6	5633,5	5797,4	1
2	4531,4	4653,4	4779,3	4909,4	5044,0	5183,6	5328,5	5479,2	5636,2	5800,2	2
3	4533,4	4655,5	4781,4	4911,6	5046,3	5186,0	5330,9	5481,7	5638,9	5803,0	3
4	4535,4	4657,5	4783,5	4913,8	5048,6	5188,3	5333,4	5484,3	5641,5	5805,8	4
5	4537,4	4659,6	4785,7	4916,0	5050,8	5190,7	5335,9	5486,9	5644,2	5808,6	5
6	4539,4	4661,7	4787,8	4918,2	5053,2	5193,1	5338,3	5489,4	5646,9	5811,4	6
7	4541,4	4663,7	4790,0	4920,4	5055,5	5195,4	5340,8	5492,0	5649,6	5814,2	7
8	4543,4	4665,8	4792,1	4922,6	5057,7	5197,8	5343,3	5494,6	5652,3	5817,0	8
9	4545,4	4667,9	4794,2	4924,8	5060,0	5200,2	5345,7	5497,1	5655,0	5819,8	9
10	4547,5	4669,9	4796,4	4927,1	5062,3	5202,6	5348,2	5499,7	5657,6	5822,6	10
11	4549,5	4672,0	4798,5	4929,3	5064,6	5205,0	5350,7	5502,3	5660,3	5825,4	11
12	4551,5	4674,1	4800,7	4931,5	5066,9	5207,3	5353,2	5504,9	5663,0	5828,2	12
13	4553,5	4676,2	4802,8	4933,7	5069,2	5209,7	5355,6	5507,4	5665,7	5831,0	13
14	4555,5	4678,2	4804,9	4935,9	5071,5	5212,1	5358,1	5510,0	5668,4	5833,9	14
15	4557,5	4680,3	4807,1	4938,1	5073,8	5214,5	5360,6	5512,6	5671,1	5836,7	15
16	4559,5	4682,4	4809,2	4940,4	5076,1	5216,9	5363,1	5515,2	5673,8	5839,5	16
17	4561,5	4684,5	4811,4	4942,6	5078,4	5219,3	5365,6	5517,8	5676,5	5842,3	17
18	4563,6	4686,6	4813,5	4944,8	5080,7	5221,7	5368,1	5520,4	5679,2	5845,2	18
19	4565,6	4688,6	4815,7	4947,0	5083,0	5224,1	5370,5	5523,0	5681,9	5848,0	19
20	4567,6	4690,7	4817,8	4949,3	5085,3	5226,5	5373,0	5525,6	5684,6	5850,8	20
21	4569,6	4692,8	4820,0	4951,5	5087,7	5228,9	5375,5	5528,2	5687,3	5853,7	21
22	4571,6	4694,9	4822,2	4953,7	5090,0	5231,3	5378,0	5530,8	5690,0	5856,5	22
23	4573,7	4697,0	4824,3	4956,0	5092,3	5233,7	5380,5	5533,4	5692,8	5859,3	23
24	4575,7	4699,1	4826,5	4958,2	5094,6	5236,1	5383,0	5536,0	5695,5	5862,2	24
25	4577,7	4701,2	4828,6	4960,4	5096,9	5238,5	5385,5	5538,6	5698,2	5865,0	25
26	4579,7	4703,2	4830,8	4962,7	5099,2	5240,9	5388,0	5541,2	5700,9	5867,9	26
27	4581,8	4705,3	4832,9	4964,9	5101,5	5243,3	5390,5	5543,8	5703,6	5870,7	27
28	4583,8	4707,4	4835,1	4967,1	5103,9	5245,7	5393,0	5546,4	5706,3	5873,5	28
29	4585,8	4709,5	4837,3	4969,4	5106,2	5248,1	5395,5	5549,0	5709,1	5876,4	29
30	4587,8	4711,6	4839,4	4971,6	5108,5	5250,5	5398,0	5551,6	5711,8	5879,3	30
31	4589,9	4713,7	4841,6	4973,9	5110,8	5252,9	5400,5	5554,2	5714,5	5882,1	31
32	4591,9	4715,8	4843,8	4976,1	5113,1	5255,3	5403,0	5556,8	5717,3	5885,0	32
33	4593,9	4717,9	4845,9	4978,3	5115,5	5257,7	5405,6	5559,5	5720,0	5887,8	33
34	4596,0	4720,0	4848,1	4980,6	5117,8	5260,1	5408,1	5562,1	5722,7	5890,7	34
35	4598,0	4722,1	4850,3	4982,8	5120,1	5262,6	5410,6	5564,7	5725,5	5893,6	35
36	4600,1	4724,2	4852,5	4985,1	5122,5	5265,0	5413,1	5567,3	5728,2	5896,4	36
37	4602,1	4726,3	4854,6	4987,3	5124,8	5267,4	5415,6	5569,9	5731,0	5899,3	37
38	4604,1	4728,4	4856,8	4989,6	5127,1	5269,8	5418,1	5572,6	5733,7	5902,2	38
39	4606,2	4730,5	4859,0	4991,8	5129,5	5272,3	5420,7	5575,2	5736,4	5905,1	39
40	4608,2	4732,6	4861,2	4994,1	5131,8	5274,7	5423,2	5577,8	5739,2	5907,9	40
41	4610,3	4734,7	4863,3	4996,3	5134,1	5277,1	5425,7	5580,5	5741,9	5910,8	41
42	4612,3	4736,9	4865,5	4998,6	5136,5	5279,5	5428,2	5583,1	5744,7	5913,7	42
43	4614,3	4739,0	4867,7	5000,9	5138,8	5282,0	5430,8	5585,7	5747,5	5916,6	43
44	4616,4	4741,1	4869,9	5003,1	5141,2	5284,4	5433,3	5588,4	5750,2	5919,5	44
45	4618,4	4743,2	4872,1	5005,4	5143,5	5286,8	5435,8	5591,0	5753,0	5922,4	45
46	4620,5	4745,3	4874,3	5007,6	5145,9	5289,3	5438,4	5593,7	5755,7	5925,2	46
47	4622,5	4747,4	4876,4	5009,9	5148,2	5291,7	5440,9	5596,3	5758,5	5928,1	47
48	4624,6	4749,5	4878,6	5012,2	5150,6	5294,2	5443,5	5599,0	5761,3	5931,0	48
49	4626,6	4751,7	4880,8	5014,4	5152,9	5296,6	5446,0	5601,6	5764,0	5933,9	49
50	4628,7	4753,8	4882,0	5016,7	5155,3	5299,0	5448,5	5604,3	5766,8	5936,8	50
51	4630,7	4755,9	4885,2	5019,0	5157,6	5301,5	5451,1	5606,9	5769,6	5939,7	51
52	4632,8	4758,0	4887,4	5021,2	5160,0	5303,9	5453,6	5609,6	5772,3	5942,6	52
53	4634,8	4760,1	4889,6	5023,5	5162,3	5306,3	5456,2	5612,2	5775,1	5945,5	53
54	4636,9	4762,3	4891,8	5025,8	5164,7	5308,8	5458,7	5614,9	5777,9	5948,5	54
55	4639,0	4764,4	4894,0	5028,1	5167,0	5311,3	5461,3	5617,5	5780,7	5951,4	55
56	4641,0	4766,5	4896,2	5030,3	5169,4	5313,7	5463,8	5620,2	5783,5	5954,3	56
57	4643,1	4768,6	4898,4	5032,6	5171,8	5316,2	5466,4	5622,9	5786,2	5957,2	57
58	4645,1	4770,8	4900,6	5034,9	5174,1	5318,6	5468,9	5625,5	5789,0	5960,1	58
59	4647,2	4772,9	4902,8	5037,2	5176,5	5321,1	5471,5	5628,2	5791,8	5963,0	59
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
D. l.	60	61	62	63	64	65	66	67	68	69	D. l.

MERIDIONAL PARTS. 143. 223

D. l.	70	71	72	73	74	75	76	77	78	79	D. l.
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
0	5966,0	6145,7	6334,9	6534,5	6745,7	6970,3	7210,1	7467,2	7744,6	8045,7	0
1	5968,9	6148,8	6338,1	6537,9	6749,4	6974,2	7214,2	7471,7	7749,4	8051,0	1
2	5971,8	6151,9	6341,4	6541,3	6753,0	6978,1	7218,3	7476,1	7754,2	8056,2	2
3	5974,7	6155,0	6344,6	6544,7	6756,6	6981,9	7222,5	7480,6	7759,0	8061,5	3
4	5977,7	6158,0	6347,8	6548,2	6760,3	6985,8	7226,6	7485,0	7763,9	8066,8	4
5	5980,6	6161,1	6351,1	6551,6	6763,9	6989,7	7230,8	7489,5	7768,7	8072,0	5
6	5983,5	6164,2	6354,3	6555,0	6767,6	6993,6	7234,9	7494,0	7773,5	8077,3	6
7	5986,5	6167,3	6357,6	6558,5	6771,2	6997,5	7239,1	7498,5	7778,4	8082,6	7
8	5989,4	6170,4	6360,9	6561,9	6774,9	7001,4	7243,3	7502,9	7783,2	8087,9	8
9	5992,4	6173,5	6364,1	6565,4	6778,5	7005,3	7247,5	7507,4	7788,1	8093,2	9
10	5995,3	6176,6	6367,4	6568,8	6782,2	7009,2	7251,6	7511,9	7793,0	8098,5	10
11	5998,3	6179,7	6370,6	6572,3	6785,8	7013,1	7255,8	7516,4	7797,8	8103,8	11
12	6001,2	6182,8	6373,9	6575,7	6789,5	7017,0	7260,0	7520,9	7802,7	8109,2	12
13	6004,2	6185,9	6377,2	6579,2	6793,2	7020,9	7264,2	7525,4	7807,6	8114,5	13
14	6007,1	6189,0	6380,5	6582,6	6796,9	7024,8	7268,4	7530,0	7812,5	8119,8	14
15	6010,1	6192,1	6383,7	6586,1	6800,5	7028,7	7272,6	7534,5	7817,4	8125,2	15
16	6013,0	6195,2	6387,0	6589,5	6804,2	7032,7	7276,8	7539,0	7822,3	8130,6	16
17	6016,0	6198,3	6390,3	6593,0	6807,9	7036,6	7281,0	7543,6	7827,2	8135,9	17
18	6019,0	6201,4	6393,6	6596,5	6811,6	7040,5	7285,2	7548,1	7832,2	8141,3	18
19	6021,9	6204,6	6396,9	6600,0	6815,3	7044,5	7289,4	7552,7	7837,1	8146,7	19
20	6024,9	6207,7	6400,2	6603,4	6819,0	7048,4	7293,7	7557,2	7842,0	8152,1	20
21	6027,9	6210,8	6403,5	6606,9	6822,7	7052,4	7297,9	7561,8	7847,0	8157,5	21
22	6030,8	6213,9	6406,8	6610,4	6826,4	7056,3	7302,1	7566,3	7851,9	8162,9	22
23	6033,8	6217,1	6410,1	6613,9	6830,1	7060,3	7306,4	7570,9	7856,9	8168,3	23
24	6036,8	6220,2	6413,4	6617,4	6833,8	7064,2	7310,6	7575,5	7861,9	8173,7	24
25	6039,8	6223,3	6416,7	6620,9	6837,6	7068,2	7314,9	7580,1	7866,8	8179,2	25
26	6042,7	6226,5	6420,0	6624,4	6841,3	7072,2	7319,1	7584,7	7871,8	8184,6	26
27	6045,7	6229,6	6423,3	6627,9	6845,0	7076,2	7323,4	7589,3	7876,8	8190,1	27
28	6048,7	6232,7	6426,6	6631,4	6848,7	7080,1	7327,7	7593,9	7881,8	8195,5	28
29	6051,7	6235,9	6429,9	6635,0	6852,5	7084,1	7332,0	7598,5	7886,8	8201,0	29
30	6054,7	6239,0	6433,2	6638,5	6856,2	7088,1	7336,2	7603,1	7891,8	8206,5	30
31	6057,7	6242,2	6436,6	6642,0	6860,0	7092,1	7340,4	7607,7	7896,8	8212,0	31
32	6060,7	6245,3	6439,9	6645,5	6863,7	7096,1	7344,8	7612,3	7901,9	8217,5	32
33	6063,7	6248,5	6443,2	6649,1	6867,5	7100,1	7349,1	7617,0	7906,9	8223,0	33
34	6066,7	6251,7	6446,6	6652,6	6871,2	7104,1	7353,4	7621,6	7911,9	8228,5	34
35	6069,7	6254,8	6449,9	6656,1	6875,0	7108,2	7357,7	7626,3	7917,0	8234,1	35
36	6072,7	6258,0	6453,3	6659,7	6878,7	7112,2	7362,0	7630,9	7922,1	8239,6	36
37	6075,7	6261,2	6456,6	6663,2	6882,5	7116,2	7366,4	7635,6	7927,1	8245,1	37
38	6078,8	6264,4	6460,0	6666,8	6886,3	7120,2	7370,7	7640,2	7932,2	8250,7	38
39	6081,8	6267,5	6463,3	6670,3	6890,1	7124,3	7375,0	7644,9	7937,3	8256,3	39
40	6084,8	6270,7	6466,7	6673,9	6893,8	7128,3	7379,4	7649,6	7942,4	8261,8	40
41	6087,8	6273,9	6470,0	6677,4	6897,6	7132,3	7383,7	7654,3	7947,5	8267,4	41
42	6090,8	6277,1	6473,4	6681,0	6901,4	7136,4	7388,0	7659,0	7952,6	8273,0	42
43	6093,9	6280,3	6476,8	6684,6	6905,2	7140,4	7392,4	7663,7	7957,7	8278,6	43
44	6096,9	6283,5	6480,1	6688,1	6909,0	7144,5	7396,8	7668,4	7962,8	8284,2	44
45	6099,9	6286,6	6483,5	6691,7	6912,8	7148,6	7401,1	7673,1	7968,0	8289,9	45
46	6103,0	6289,8	6486,9	6695,3	6916,6	7152,6	7405,5	7677,8	7973,1	8295,5	46
47	6106,0	6293,0	6490,3	6698,9	6920,4	7156,7	7409,9	7682,6	7978,2	8301,1	47
48	6109,1	6296,2	6493,6	6702,4	6924,2	7160,8	7414,2	7687,3	7983,4	8306,8	48
49	6112,1	6299,4	6497,0	6706,0	6928,1	7164,9	7418,6	7692,0	7988,5	8312,4	49
50	6115,1	6302,7	6500,4	6709,6	6931,9	7169,0	7423,0	7696,8	7993,7	8318,1	50
51	6118,2	6305,9	6503,8	6713,2	6935,7	7173,0	7427,4	7701,5	7998,9	8323,8	51
52	6121,2	6309,1	6507,2	6716,8	6939,5	7177,1	7431,8	7706,3	8004,0	8329,4	52
53	6124,3	6312,3	6510,6	6720,4	6943,4	7181,2	7436,2	7711,0	8009,2	8335,1	53
54	6127,4	6315,5	6514,0	6724,0	6947,2	7185,3	7440,6	7715,8	8014,4	8340,8	54
55	6130,4	6318,7	6517,4	6727,6	6951,1	7189,5	7445,0	7720,6	8019,6	8346,6	55
56	6133,5	6322,0	6520,8	6731,2	6954,9	7193,6	7449,5	7725,4	8024,8	8352,3	56
57	6136,5	6325,2	6524,2	6734,9	6958,8	7197,7	7453,9	7730,2	8030,0	8358,0	57
58	6139,6	6328,4	6527,6	6738,5	6962,6	7201,8	7458,3	7735,0	8035,3	8363,7	58
59	6142,7	6331,7	6531,0	6742,1	6966,5	7205,9	7462,8	7739,8	8040,5	8369,5	59
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
D. l.	70	71	72	73	74	75	76	77	78	79	D. l.

D. I.	80	81	82	83	84	85	86	87	88	89	D. I.
min.	M.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
0	8375,3	8739,1	9145,5	9605,9	10137,0	10764,7	11532,6	12522,3	13916,6	16299,8	0
1	8381,0	8745,5	9152,7	9614,1	10149,6	10776,2	11547,0	12541,4	13945,4	16357,5	1
2	8386,8	8751,9	9159,9	9622,4	10156,2	10787,7	11561,4	12560,7	13974,4	16416,3	2
3	8392,6	8758,3	9167,2	9630,6	10165,8	10799,3	11575,9	12580,0	14003,7	16476,1	3
4	8398,3	8764,8	9174,4	9638,9	10175,4	10810,8	11590,5	12599,5	14033,2	16537,0	4
5	8404,1	8771,2	9181,6	9647,2	10185,1	10822,6	11605,0	12619,1	14063,0	16598,9	5
6	8409,9	8777,7	9188,9	9655,5	10194,8	10834,2	11619,7	12638,8	14093,0	16662,0	6
7	8415,8	8784,1	9196,2	9663,8	10204,6	10845,9	11634,5	12658,6	14123,3	16726,2	7
8	8421,6	8790,6	9203,5	9672,2	10214,4	10857,7	11649,3	12678,6	14153,9	16791,7	8
9	8427,4	8797,1	9210,8	9680,0	10224,2	10869,6	11664,1	12698,6	14184,7	16858,5	9
10	8433,3	8803,6	9218,1	9689,0	10234,0	10881,4	11679,1	12718,8	14215,8	16926,5	10
11	8439,1	8810,1	9225,4	9697,4	10243,8	10893,3	11694,0	12739,1	14247,2	16995,6	11
12	8445,0	8816,6	9232,7	9705,8	10253,7	10905,2	11709,1	12759,5	14278,9	17066,9	12
13	8450,9	8823,2	9240,2	9714,2	10263,6	10917,2	11724,2	12780,0	14310,9	17140,3	13
14	8456,8	8829,7	9247,6	9722,7	10273,5	10929,1	11739,4	12800,7	14343,2	17213,2	14
15	8462,6	8836,3	9255,0	9731,2	10283,5	10941,2	11754,7	12821,5	14375,8	17288,7	15
16	8468,6	8842,8	9262,4	9739,7	10293,5	10953,3	11770,0	12842,5	14408,7	17366,0	16
17	8474,5	8849,4	9269,9	9748,3	10303,5	10965,5	11785,4	12863,5	14441,9	17444,0	17
18	8480,4	8856,0	9277,3	9756,8	10313,6	10977,7	11800,9	12884,7	14475,4	17525,9	18
19	8486,3	8862,6	9284,8	9765,4	10323,7	10989,9	11816,4	12906,0	14509,3	17608,7	19
20	8492,3	8869,3	9292,3	9774,0	10333,8	11002,2	1182,0	12927,4	14543,5	17694,6	20
21	8498,2	8875,9	9299,8	9782,7	10344,0	11014,5	11847,6	12948,9	14578,1	17780,5	21
22	8504,2	8882,6	9307,3	9791,3	10354,1	11026,9	11863,4	12970,6	14613,0	17869,9	22
23	8510,2	8889,2	9314,8	9800,0	10364,3	11039,3	11879,2	12992,5	14648,3	17961,6	23
24	8516,2	8895,9	9322,4	9808,6	10374,5	11051,7	11895,1	13014,4	14683,9	18055,8	24
25	8522,2	8902,6	9330,0	9817,3	10384,8	11064,2	11911,0	13036,6	14719,9	18152,6	25
26	8528,1	8909,3	9337,6	9826,1	10395,0	11076,8	11927,1	13058,8	14756,3	18252,3	26
27	8534,2	8916,0	9345,2	9834,8	10405,3	11089,3	11943,1	13081,2	14793,0	18354,9	27
28	8540,2	8922,7	9352,8	9843,6	10415,7	11102,0	11959,3	13103,8	14830,2	18460,7	28
29	8546,2	8929,5	9360,4	9852,4	10426,2	11114,6	11975,6	13126,5	14867,8	18569,8	29
30	8552,3	8936,2	9368,1	9861,3	10436,6	11127,4	11991,9	13149,3	14905,8	18682,5	30
31	8558,4	8943,0	9375,8	9870,1	10447,1	11140,1	12008,4	13172,3	14944,2	18799,1	31
32	8564,4	8949,8	9383,5	9879,0	10457,5	11152,9	12024,9	13195,5	14983,0	18919,7	32
33	8570,5	8956,6	9391,2	9887,8	10468,0	11165,8	12041,5	13218,8	15022,3	19044,7	33
34	8576,6	8963,4	9398,9	9896,7	10478,5	11178,7	12058,2	13242,3	15062,1	19174,4	34
35	8582,7	8970,2	9406,6	9905,7	10489,1	11191,7	12074,9	13265,9	15102,3	19309,2	35
36	8588,9	8977,1	9414,4	9914,6	10499,7	11204,7	12091,7	13289,7	15143,0	19449,5	36
37	8595,0	8983,9	9422,1	9923,6	10510,4	11217,7	12108,6	13313,7	15184,2	19595,8	37
38	8601,1	8990,8	9429,9	9932,7	10521,1	11230,8	12125,6	13337,8	15225,8	19748,6	38
39	8607,3	8997,7	9437,8	9941,7	10531,8	11244,0	12142,7	13362,1	15268,0	19908,5	39
40	8613,5	9004,6	9445,6	9950,8	10542,6	11257,2	12159,9	13386,6	15310,7	20076,4	40
41	8619,6	9011,5	9453,4	9959,8	10553,3	11270,5	12177,1	13411,2	15353,8	20252,5	41
42	8625,8	9018,4	9461,3	9968,9	10564,1	11283,8	12194,4	13436,1	15397,8	20433,3	42
43	8632,0	9025,4	9469,1	9978,0	10574,9	11297,1	12211,8	13461,1	15442,1	20615,1	43
44	8638,2	9032,3	9477,0	9987,2	10585,8	11310,5	12229,3	13486,3	15486,9	20843,5	44
45	8644,5	9039,3	9484,9	9996,3	10596,7	11324,0	12246,9	13511,6	15532,6	21065,4	45
46	8650,7	9046,3	9492,9	10005,5	10607,6	11337,6	12264,6	13537,0	15578,7	21302,5	46
47	8656,9	9053,3	9500,8	10014,8	10618,6	11351,1	12282,4	13562,8	15625,5	21557,3	47
48	8663,2	9060,3	9508,8	10024,0	10629,7	11364,8	12300,2	13588,9	15672,7	21832,5	48
49	8669,5	9067,3	9516,8	10033,3	10640,8	11378,4	12318,1	13615,1	15721,0	22131,6	49
50	8675,7	9074,4	9524,8	10042,6	10651,9	11392,2	12336,3	13641,4	15769,8	22459,3	50
51	8682,0	9081,4	9532,9	10051,9	10663,0	11406,0	12354,4	13667,8	15819,3	22821,5	51
52	8688,3	9088,5	9540,9	10061,3	10674,1	11419,8	12372,7	13694,5	15869,4	23226,4	52
53	8694,6	9095,6	9548,9	10070,6	10685,3	11433,7	12391,0	13721,5	15920,4	23685,4	53
54	8701,0	9102,7	9557,0	10080,0	10696,5	11447,7	12409,5	13748,9	15972,1	24215,3	54
55	8707,3	9109,8	9565,1	10089,4	10707,7	11461,7	12428,0	13776,1	16024,6	24842,1	55
56	8713,6	9116,9	9573,2	10098,9	10719,1	11475,8	12446,5	13803,7	16077,9	25609,2	56
57	8720,0	9124,0	9581,4	10108,4	10730,4	11489,9	12465,3	13831,5	16132,0	26598,2	57
58	8726,4	9131,2	9589,5	10117,9	10741,8	11504,1	12484,2	13859,6	16187,0	27992,1	58
59	8732,7	9138,4	9597,7	10127,4	10753,3	11518,3	12503,1	13887,8	16242,9	30375,0	59
min.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	M. P.	min.
D. I.	80	81	82	83	84	85	86	87	88	89	D. I.



THE
ELEMENTS
OF
NAVIGATION.

BOOK IX.

OF DAYS WORKS.

I. **BY DAYS WORKS** are here meant the practical methods of finding a ship's place every day at noon, and settling the course and distance she has then to sail.

The navigator requires for this purpose the following elements, or necessary things, to be known:

- I. The means of measuring and correcting the run of the ship.
- II. The nature and use of the sea and azimuth compasses.
- III. How to find the Sun's amplitude and azimuth.
- IV. How to find the variation of the compass, and to correct the courses the ship has sailed on that account.
- V. How to find the ship's lee-way, and thence to correct the courses.
- VI. The nature and use of instruments proper for observing the altitudes and distances of celestial objects.
- VII. How to find the latitude and longitude by celestial observations.
- VIII. How to correct the daily account of latitude and longitude.

SECTION I.

2. *Of the measuring a Ship's run.*

A great variety of methods has been proposed to measure the rate at which a ship sails, but that mostly in use at this time, especially among the English, is by the *log and half minute glass*.

The LOG is a piece of thin board, of a sectoral or quadrantal form, loaded in the circular side with lead sufficient to make it swim upright in the water: to this is fastened a line about 150 fathoms long, called the LOG-LINE, which is divided into certain spaces, called knots; and the log-line is wound on a reel, which turns very easily.

The HALF MINUTE GLASS is of the form of an *hour-glass*, and contains such a quantity of fine sand, as will run through the hole in its neck in half a minute of time.

The making of the experiment to find the velocity of the ship is called HEAVING THE LOG, which is thus performed:

One man holds the reel, and another the half minute glass; an officer of the watch throws the log over the ship's stern, on the lee side, and when he observes the stray line is run off the reel (which is about 10 fathoms, this distance being usually allowed to carry the log out of the eddy of the ship's wake) and the first mark is going off, he cries *turn!* the glass-holder answers *done!* who watching the glass, the moment it is run out says *stop!* the reel being immediately stopt, the last mark run off shews the number of knots, and the distance of that mark from the reel is estimated in fathoms. Then the knots and fathoms, together, shew the distance the ship has run the preceding hour, if the wind has been constant.

In the King's ships, India ships, and some others, it is usual to heave the log every hour: but coasters, and those which make short voyages, heave the log once in two hours only.

3. This practice of measuring a ship's rate of sailing is founded upon the following principle.

That the length of each knot ought to be the same part of a sea mile; as half a minute is of an hour.

Therefore the length of each knot should be either

$$\begin{aligned} & \left(\frac{1}{2} \times \frac{1}{60} \right) = \frac{1}{120} \text{ of a nautical mile.} \\ \text{Or } & \left(\frac{1}{2} \times \frac{1}{60} \times \frac{1}{60} \right) = \frac{1}{7200} \text{ of a degree.} \\ \text{Or } & \left(\frac{1}{2} \times \frac{1}{60} \times \frac{1}{60} \times \frac{1}{60} \right) = \frac{1}{259200} \text{ of a great circle.} \end{aligned}$$

By Mr. Richard Norwood's experiment (see V. 73) it appears, that a degree of a great circle on the Earth contains 367200 English feet, and $\frac{1}{60}$ thereof, or 6120 feet, is the length of one nautical mile.

Hence $\frac{1}{120}$ th of 6120, or 51 feet, should be the length of each knot.

But because it is safer to have the reckoning rather before the ship than after it, therefore 50 feet may be taken as the proper length of each knot; and each knot is now usually divided into 8 fathoms.

The

The length of the knots in the log-line, used formerly, was only 42 feet; and it is much to be wished that no line so divided was now in use, but custom in many things prevails over reason. This way of dividing the log-line was founded on the supposition that 60 miles, each of 5000 English feet, made a degree; for $\frac{1}{120}$ of 5000 is $41\frac{2}{3}$, or in round numbers 42 feet. And although many mariners find by experience that this length of the knot is too short, yet rather than quit the *old way*, they use glasses for half minute ones that run but 24 or 25 seconds.

The method usually recommended to try if the glasses are accurate, is this: On a round nail or peg hang a small thread that has a musket-ball fixed to one end, 39 $\frac{1}{8}$ inches being carefully measured from the center of the ball to the loop which goes over the peg. Then make it swing, and count one for every time it passes under the peg, beginning at the second time it passes, and the number of swings which it makes during the time the glass is running out, shews the seconds which that glass runs.

For experience shews, that the length of a second pendulum is about 39 $\frac{1}{8}$ inches.

The distance given by the log may be wrong on three accounts; namely, by an error either in the glass, or the log-line, or in both.

4. CASE I. *When the log-line is truly divided, and the glass is faulty.*

RULE. As the seconds run by the glass, are to 30 seconds;
So is the distance run by the log, to the true distance.

EXAM. Suppose a ship sails at the rate of $6\frac{1}{2}$ knots while a glass runs out, which runs only 25 seconds: What is the true rate of sailing?

As 25 : 30 :: 6,5 : 7,8 miles, the true distance sailed in an hour.

5. CASE II. *When the glass is true, and the log-line is faulty.*

RULE. As 50 feet, is to the distance measured between knot and knot;
So is the distance run by the log, to the true distance.

EXAM. Suppose a ship sails at the rate of $6\frac{1}{2}$ knots an hour, by a log-line which has only 44 feet to a knot: What is the true rate of sailing?

As 50 : 44 :: 6,5 : 5,72 miles, the true distance sailed in an hour.

6. CASE III. *When both log-line and glass are faulty.*

RULE. Multiply thrice the measured length of a knot by the distance run per log; the product, divided by five times the measured time of the glass, will give the true distance run.

EXAM. Suppose a ship runs 5 knots an hour, by a log-line of 45 feet to a knot, and a glass of 25 seconds: What is the true rate of sailing?

Then $3 \times 45 \times 5$, and divided by 5×25 , gives 5,4 miles = true dist.

For suppose K = meas. length of a knot; G = seconds per glass; D = run per log.

Then $G : 30 :: D : 30 \times D \div *G$ = dist. run by a correct glass. (4)

And $50 : K :: 30 \times D \div G : 30 \times D \times K \div G \times 50 = 3 \times D \times K \div 5 \times G$.

* The mark $\div$ signifies divided by.

The log is subject to drive with the motion which the water may have at its surface, and thereby give an erroneous rate of sailing (for the experiment supposes the *log* fixed in the place where it is, when the first knot goes off the *reel*); therefore many methods have been proposed to remove, or at least to lessen this error; and among them, that seems most worthy of notice, which was proposed by the late M. *Bouguer**, in his *Treatise on Navigation*, published at Paris in the year 1753, and which was composed by the order of the Minister of State; and again reprinted there in the year 1760, with some alterations, by the late Abbé de la Caille; both those gentlemen had been separately engaged in very long voyages, and consequently had much marine experience: the substance of this method will be here given, though somewhat differently drawn up.

7. Take for the LOG a conical piece of wood, through, or along the axis of which the log-line must be passed, and made fast to it, about 40, 50, 60, or more feet from one end; and to this end fix the DIVER, which is a body formed of two equal square pieces of tin, or of thin iron plate, fixed at right angles to one another along their diagonals. The size of this diver must be so fitted to that of the cone, that the cone may just float.

A cone of three inches diameter in the base, and of six inches in the slant height, is proposed by M. Bouguer, to suit a diver made of plates about $9\frac{1}{4}$ inches square. The float is fixed to the log-line at the intersection of the diagonals; and the *loop* and *peg* used as in the common log.

When this compound log is hove overboard, the diver will sink too deep to be much affected by the current, or motion of the water at the surface; and the log will keep more steadily in the place where it first fell; and consequently, the knots run off the reel will shew more accurately the ship's rate of sailing.

As the common log is affected by the whole motion of the current, so this compound log will feel only a part of it; *viz.* such a part nearly, as the resistance of the *cone* is of the resistance of the *diver*: thus the resistances of the above cone and diver are about as 1 to 5; and consequently this log will drive but $\frac{1}{5}$ part of what the common log would; and so the ship's true run will be affected by $\frac{1}{5}$ part only of the motion of the waters.

8. To obtain the true rate of sailing, it will be proper to heave alternately, hour and hour, the common log and this compound log. Then the difference of their knots run off, augmented by its $\frac{1}{4}$ th part, is the correction; which applied to the knots of the common log will give the ship's true rate of sailing, at the middle time between the hours when those logs were hove. The correction is added when the run by the compound log is greatest; otherwise it is subtracted.

9. To find the course made good. Increase the observed angle between the log-lines by one fourth part; and this gives the correction to be applied to the apparent course, or the opposite of that shewn by the common log.

* The French Academician concerned in measuring a degree of a meridian in Peru.

The correction is to be applied to the $\left\{ \begin{smallmatrix} \text{right} \\ \text{left} \end{smallmatrix} \right\}$ of the apparent course.

When the bearing of the common log is to the $\left\{ \begin{smallmatrix} \text{left} \\ \text{right} \end{smallmatrix} \right\}$ of the comp. log.

10. Or thus: The length run off both logs, together with their bearings, being known, on a card or compass apply the knots run off (taken from a scale of equal parts) along their respective bearings, from the center; join the ends, and in this line produced, on the side next the compound log's length, take $\frac{1}{4}$ of the interval; then a line drawn from the end, thus produced, to the center of the card, will shew the true course and distance made good.

Or, the true course and distance may be found by computation; by working in the two triangles formed by the above construction.

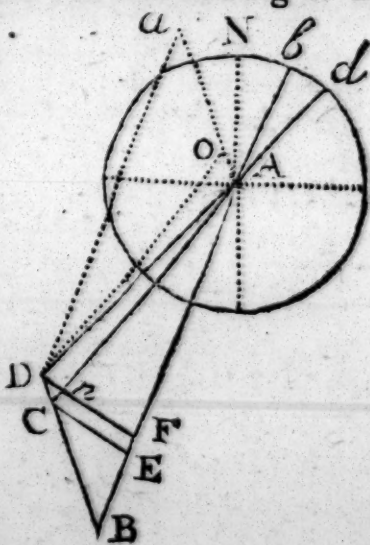
Ex. I. The common log having run 6,7 knots, bore N. 42° E. at 9 h. 30 m. A. M. and at 11 h. 30 m. A. M. the compound log having run off 8,3 knots, it bore N. 37° E.: Required the correct course and rate of sailing at 10 h. A. M.

Common. log.	Run 6,7k.	bear. N. 42° E.
Comp. log.	8,3k.	N. 37 E.
Diff.	1,6	5
$\frac{1}{4}$ part	0,4	$1\frac{1}{4}$
Correction	2,0	$6\frac{1}{4}$
True run	8,7	Bear. S. 35 $\frac{1}{4}$ ° W.

Ex. II. At 5 h. P. M. the common log having run off 7,6 knots, it bore S. 18° W.; and at 7 h. P. M. the compound log having run off 5,2 knots, it bore S. 26° W.: Required the true course and rate at 6 h. P. M.

Common. log.	Run 7,6k.	Bear. S. 18° W.
Comp. log.	5,2	S. 26 W.
Diff.	2,4	8
$\frac{1}{4}$ part	0,6	2
Correction	3,0	10
True run	4,6	Bear. N. 28° E.

11. The following explanation of Ex. II. will shew the reason of these corrections. Suppose the line AB to represent the run and bearing of the ship by the common log; and AC the run and bearing by the compound log; and let the ship be supposed at D when the logs were hove. Then her apparent run by the wind, with the common log, is the line Da, or its parallel BA, while the log is driven by the current along the line DB; so that the ship's real run is along the line DA (VII. 48). Also, by the compound log, the ship's apparent run by the wind is the line Dc, or its parallel CA; while the log drives from D to C, which is only $\frac{1}{4}$ th part of DB; so the real run is DA. Take EB = AB $\cap$ AC; draw CE and its parallel DF; then is EF = $\frac{1}{4}$ EB (II. 165), AF is nearly equal to AD, and $\angle DAC$ is very nearly equal to $\frac{1}{4}\angle BAC$.



For $An = AF$ (II. 165) : and An in the time of making the experiment cannot differ much from AD ; neither can Dn differ much from $\frac{1}{4}$ of Fn ; consequently the $\angle DAN$ is very nearly equal to $\frac{1}{4} \angle FAn$.

Therefore AF being known gives the run DA . Also the bearing AB being known by observation, or its opposite Ab ; and the $\angle ABD$ found by correction, the bearing DA , or the real course, becomes known.

Or: Computing in the triangle BAC , with the two sides, and the included angle, find $\angle BCA$ and BC : then in the triangle ACD , knowing AC , $CD (= \frac{1}{4}BC)$, and $\angle ACD$; find $\angle CAD$ and AD .

12.

REMARK.

I. There seems to be a mistake in the dimensions of the cone, and diver, proposed by M. Bouguer, and followed by M. de la Caille; for no kind of wood used in British dock-yards, when formed into a cone of those dimensions, will float a diver made of stout tin plates, one side of the square being $9\frac{1}{4}$ inches. Such a diver, weighing $1\frac{7}{8}$ lb. avoirdupois, required to float it a cone of 5 inches diameter, and 12 inches on the slant side, so that the point of the cone, which was made of light fir, should just appear above the water. Now supposing one side of such a square tin diver to be about 10 inches, and made of plate only $\frac{2}{3}$ of the thickness of the former (for it is suspected there is no tin of half its thickness), such a diver would weigh, with its folder, about 20 ounces, and can be floated by a light fir cone of 4 inches diameter in the base, and 10 inches in the slant height, or length; and such a compound log might, perhaps, be found on trial to be affected by about as much again as that proposed by M. Bouguer, and consequently *the difference between the numbers given by the common log and compound logs, must be augmented by $\frac{2}{3}$ of itself to produce the necessary correction.*

13. II. When a current, such as a tide, runs to any depth, the velocity of that current may be much better ascertained by the compound log, than by the common one, provided the diver does not descend lower than the run of the current; for as those ships which are deepest immersed, drive fastest with the tide, so the diver being acted on below, as well as the log on the surface, their joint motion will give the total effort of the current's motion, better than what could be derived from the motion at the surface only. Also, by such a compound log, the depth to which any current runs, may be easily tried.

SECTION II.

Of the Mariner's Compass.

14. The MARINER'S COMPASS is an instrument used at sea to point out the way a ship does, or is to go; and consists of three parts, namely, the box, the card or fly, and the needle.

The Box, which contains the card and needle, is a circular brass box hung within a square wooden one, by two concentric rings, called *jimbals*, so fixed by cross centers to the two boxes, that the inner one, or compass box, shall retain an horizontal position in all motions of the ship.

The CARD, or FLY, is a circle of stiff paper representing the horizon; and is divided into points and quarter points of the compass.

The NEEDLE is a strait piece of steel made magnetical; which has the property of pointing with one of its ends towards the north pole of the world.

The needle is fixed to the under side of the card, and in the center is placed a conical socket, which is put on an upright pointed pin, fixed in the bottom of the box; so that the card, hanging on the pin, turns freely round its center; and one of the points, by the property of the needle, will always be directed towards the north pole *.

The top of the box is covered with a glass pane, that the motion of the card may not be disturbed by the wind. This apparatus is called the *Compass*. The compass box is to be so placed in the ship, that the middle section of the box, parallel to its sides, may be parallel to the middle section of the ship, along its keel.

15. Before the invention of the compass, which happened towards the latter end of the 13th century, the navigating of ships was a very tedious and precarious operation, and seldom made out of sight of land. But the compass enables the mariner to hold his course over the seas in as direct and true a track, as the land carrier directs his carriage in a well-beaten road. Hence it might be reasonably imagined, that no necessary expence or care should ever be wanting in the construction of this most useful instrument. But it has so happened, that some years ago scarce one sea compass in ten was fit for the use for which it was made; they were fabricated by unskilful and ignorant workmen for the wholesale dealers in the shipping way: and such dealers generally pay no more regard to the construction of this instrument, on which the success of the voyage, and the lives of the men, in a great measure depend, than they do to any indifferent thing of the same price.

* If a magnet, or a piece of iron made magnetical, be suspended by a thread, or floated on a piece of light wood or cork in a vessel of water; let the body be turned round either eastward or westward, one and the same point will always be turned towards the north when the body becomes at rest.

There are however compasses used in the Royal Navy, India ships, and some few trading ships, which are constructed with more care, and on better principles; and are therefore vastly preferable to those commonly used in the merchant's service, which, from their construction, seem to have been contrived purposely to vary from what was to be expected of them; as by joining the outside box together with iron nails; making the needle of soft wire; and disposing it in the form of a rhombus, in expectation that the magnetical forces of the sides would conspire to act in the diagonal; making the pin and socket so badly, as to prevent the card from traversing, &c. &c.

It is only within a few years, that sea-compasses have been made free from that multitude of inconveniences which formerly attended the best of them: Such inconveniences were, first, needles having several poles, occasioned by their irregular shape; for the best kind are straight bars with flat ends. 2d. The needles being made of such a temper as was capable neither of receiving, nor of retaining half the virtue it is possible to give them; and consequently, they were not directed to the poles with that strength and perseverance they might have been. 3d. The want of proper means to restore their magnetism during the course of a voyage, when it has been impaired. 4th. The troublesome and inaccurate methods of repairing the pin on which the card turned when it has been damaged, and also the expence attending the use of agate caps, or sockets, which are the most proper. 5th. The want of proper contrivances to hinder the card from being greatly affected by the various motions of the ship. These, and several other imperfections, have been happily removed by the labours of the truly celebrated Dr. *Gowen Knight*, F. R. S. whose admirable invention of giving magnetism to steel bars, greatly superior to any power they could derive from the natural loadstones, joined to a multitude of experiments which he has made for the marine service, has produced the means of constructing sea-compasses so perfect, that there seems nothing farther to be wished for, as necessary to this instrument. It may be reasonably expected, that such correct compasses will readily be brought into general use, as well in merchant's ships as in ships of war; for Knight's compasses are now universally used in the royal navy.

16. After the discovery of that most useful property of the magnet, or loadstone, namely, its giving a polarity to hardened iron or steel, the compass was for many years used, without knowing that its direction in any wise deviated from the poles of the world: about the middle of the 16th century, so certain were some of its inflexibly pointing to the north, that they treated with contempt the notion of the variation, which about that time began to be suspected. However, careful observations soon discovered that in England, and its neighbourhood, the needle pointed to the eastward of the true north: and the quantity of this deviation being known, mariners became as well satisfied as if the compass had none; because the true course could be obtained by making allowance for the true variation.

From successive observations made afterwards, it was found that the deviation of the needle from the north was not a constant quantity; but that

that it gradually diminished, and at last, namely, about the year 1657, it was found at London, that the needle pointed due north, and has ever since been getting to the westward, and now the variation is near 22 degrees to the westward of the north: So that in any one place it may be suspected the variation has a kind of libratory motion, traversing through the north to unknown limits eastward and westward. But the settling of this point must be left to time.

About the same time it was also discovered, that the variation of the needle was different in different parts of the world, it being west in some places when it was east in others; and in places where the variation was of the same name, yet the quantity of it differed greatly. It was therefore found necessary that mariners should, every day, or as often as they had opportunity, make proper observations of the sun's amplitude or azimuth, by which they might be enabled to find the variation of the compass in the place they were then, and thence correct their courses properly.

17. Besides the common sea-compass, there is another, called the **AZIMUTH COMPASS**, the use of which is to take the bearing of any celestial object, when it is in, or above the horizon. This compass differs in no respect from the other, only that the circumference of the card or box is divided into degrees; and there is fitted to the box an index with two sights, which are upright pieces of brass, placed diametrically opposite to each other, having slits down their middles, through which the sun or star is to be viewed at the time of observation.

18.

To make Artificial Magnets.

As there are many accidents at sea, which make it very convenient, and even necessary, for mariners to know how to restore the magnetic virtue to their damaged needles, it was judged proper to shew how, independent of a loadstone, magnetism might be given to steel bars; and with these bars to touch the needles of their compasses.

The following method is extracted from a paper given by Mr. John Canton, F. R. S. in the Philosophical Transactions for the year 1750.

Procure six bars of soft steel, about 3 inches long, $\frac{1}{4}$ inch broad, and $\frac{1}{20}$ thick; and other six of the hardest steel, each of double those dimensions; and let each of the 12 bars be marked with a line round them at one end, which call the north end; and the other, the south end. Procure also four bars of soft iron, called conductors; two of the same thickness and breadth, but only half the length of the soft bars; the other two, alike proportioned to the hard bars; have ready also an iron poker and tongs that have been long in use.

Let the poker be held nearly upright, with its point downwards; and let one of the soft steel bars be held tightly against the middle of the poker by a thread with its N. end downwards; then with the lower end of the tongs, held also nearly upright, stroke the steel bar from the N. end upwards, about 10 times, on both sides: and in this manner serve four of the soft steel bars; and each will be made able to suspend a small key by its N. end.

Lay

Lay the other two soft steel bars in a parallel position, at the distance of $\frac{1}{4}$ inch, with a N. and S. end to touch each of their proper conductors. Then placing two of the touched steel bars together, breadth to breadth, the N. end of one to the S. end of the other; and the other two put in like manner against these, one on each side, so as to have two north ends together, and also two south ends; separate with a large pin the two north points from the two south points, at one end; and to the middle of one of the two soft bars apply the open end of the compound bar, held upright, with the two norths towards the south end of the lying bar, and in this position slide the compound bar backwards and forwards four times the whole length of the lying bar, ending at the middle; from whence remove the compound bar to the middle of the other lying one, which rub in like manner: then turn both bars the other side upwards, and repeat the operation on each. Let the two lying bars make the inner two of the compound one, and place those which were before the two outside ones between the conductors, on which the operation of rubbing is to be performed with the end of the compounded bar. Repeat this operation until each pair of bars has been rubbed four times, and their magnetic power will be greatly increased.

Now putting three contiguous N. ends to three S. ends, with this compound bar, the lower ends being opened with a pin, as before, touch two pairs of the hard bars, placed at half an inch distance, between their proper conductors, in the manner above described; and with these four touched bars make a compound one to touch the other pair; observing that the lower ends be parted near a quarter of an inch after they are set on the middle of the lying bar, and that they are closed before they are taken off: touch each pair of hard bars three times over, and these bars will be strongly magnetical. To make them more so, let each pair, lying between their conductors, be touched twice over by two others, held as nearly horizontal as can be, one in each hand, by drawing at the same time the N. end of one from the middle of the lying bar over its S. end; and the S. end of the other from the middle over the N. end, and bringing them every time to the middle of the lying bar without touching it. Four of these horizontal strokes along each side will give as much magnetic strength to the hard bars as they seem capable of receiving; and each bar, if well hardened, will lift near two pounds weight avoirdupois.

19.

To preserve these Artificial Magnets.

The six hard bars, with their two conductors put end to end as one bar, should be kept in a case; the bars being put face to face, having a N. and S. end together alternately; thus they will retain their virtue a long time, and be ready for any experiments: and should their power be found to fail, it may be restored, by the latter part of the operation, in a few minutes.

20.

To give Magnetism to Compass Needles.

Lay the two needles of equal length, about an inch asunder, with the N. end of one and S. end of the other pointing the same way, and apply two conductors in contact with their ends. Then with two magnetic hard bars, one in each hand, and held as nearly horizontal as can be with the upper ends of contrary names turned outwards to the right and left, let a needle be stroked or rubbed from the middle to both ends at the same time, for 10 or 12 times, a N. end of a bar going over the S. end of the needle, and the S. end of a bar going over the N. end of a needle. Then without moving from the place, change hands with the bars, or, in the same hands, turn the other ends downwards, and stroke the other needle in like manner, and they will both be magnetical. But to make them still stronger, repeat the operation three or four times from needle to needle; and at last turn the lower side of each needle upwards, and repeat the operations of rubbing them, as on the other sides.

In the rubbings or touchings to procure magnetism, the hand should not return directly back the way it came, but should return in a kind of oval figure, carrying the hand about six or eight inches beyond the point of the bar or needle where the touch ended; but not beyond the point on the side where the touch begins.

It may be proper to observe, that the needle, which before it was made magnetical, hung level on its pivot, does afterwards incline to the horizon; which inclination is called its *Dip*: The horizontality is to be restored by putting a small counterpoise, or ring of brass wire, on to that end of the needle which appears to be the lightest.

P R O B L E M.

To make an observation with the Azimuth Compass.

21.

I. FOR AN AMPLITUDE*.

When the center of the sun is about one of his diameters above the horizon, turn the compass round in the box, until the center of the sun may be seen through the narrow slit which is in one of the sight vanes, exactly on the thread which bisects the slit in the other, at that instant push the stop which is in the side of the box against the edge of the card, and the degree, and parts of a degree, which stand against the middle line on the stop, is the amplitude of the sun for that time.

22.

II. FOR AN AZIMUTH†.

Turn the compass round in the box until the center of the sun may be seen through the narrow slit, which is in one of the sight vanes, exactly on the thread which bisects the slit in the other; or, until the shadow of

* Amplitudes are from observations made on objects in the horizon. See Book V. 112, 147 to 152.

† Azimuths are from observations made on objects above the horizon. See Book V. 111, 152.

that thread falls directly along the line of the index : when either of these is effected, push in the stop against the edge of the card, and that degree and parts of a degree which stand against the middle line on the stop is the azimuth of the sun at that time.

What is here said of the sun, is in like manner to be applied to the stars.

23. When there is a rough sea, and the ship rolls much, the observation is best performed by two persons, thus :

Let one look through the sights, and turn them till the thread cuts the center of the sun, and be sure to keep a constant sight of it, notwithstanding the motion of the ship, which being signified to the assistant by any word, let him that instant observe what degree of the card is against the middle line of the stop, and the arc intercepted between that point and the meridian will shew the quantity of the magnetic amplitude or azimuth. If the card should vibrate very much, let him take the middle degree between the limits to which the vibrations extend.

When the magnetic azimuth of any object is observed, its altitude must also be taken at the same time.

This instrument is also useful in setting the ship's wake, in order to find the lee-way ; and also to find the bearings of headlands and other objects.

SECTION III.

24. *To work an Amplitude.*

The true amplitude of a celestial object is its distance from one of the cardinal points of the horizon, at the rising or setting of that object.

The amplitude is reckoned eastward in the morning ; but it is named westward in the evening.

The customary way of accounting the amplitude is, to reckon it so much to the southward or northward of the east in the morning ; and in the evening so much to the southward or northward of the west : but as bearings are generally taken from the meridian, in the following pages the amplitudes will be estimated chiefly from the north point of the horizon.

The finding of the true amplitude at sea is of considerable importance in navigation ; for the true course which the ship has steered is partly ascertained thereby.

PROBLEM.

25.

*Given the latitude of the place, and the declination of a celestial object :
Required the true amplitude of that object.*

SOLUTION.

Say : As the co-sine of the latitude is to radius.

So is the sine of the given decl. to the co-sine of the amplitude.

Or, Add 10 to the index of the log. sine of the declin. and subtract the log. co-sine of the latitude from the sum, the remainder is the log. co-sine of the true amplitude.

The amplitude, thus found, is to be reckoned from that point of the horizon or compass, which is of the same name with the declination of that object.

If the amplitude be wanted from the east or west points of the horizon, the last term of the proportion will be a sine instead of a co-sine ; and the amplitude is to be taken to the northward of those points, when the declination is north ; or to the southward, when the declination is south.

26.

SOLUTION BY THE TRAVERSE TABLE.

With the declination among the courses, find the departure to the distance 100.

With the given latitude among the courses, and said departure in the column of latitude, find the distance.

Look for a column of departure, where this distance stands against 100 in the column of distance, and the degrees in the corresponding course will give the amplitude from the east or west.

This rule will always give the degrees as truly as by logarithms : and as the magnetic amplitude cannot be observed more exactly, the true amplitude will be had sufficiently correct by this rule.

EXAM. I. *In the latitude of $38^{\circ} 25' N$. what is the Sun's true amplitude when his declination is $18^{\circ} 59' N$. ?*

By Logarithms.			By the Traverse Table.
As cof. lat.	= $38^{\circ} 25'$	0,10595	To decl. $19^{\circ} 00'$, and dist. 100, the dep. is 32,56.
To radius	= R	10,00000	
So sin. decl.	= $18^{\circ} 59'$	9,51227	To lat. $38^{\circ} 25'$, and diff. lat. 32, the dist. is 41.
To fin. hor. arc	= $24^{\circ} 32'$	9,61822	
Subtract from	90 00 for N. dec.		To dist. 100, and dep. 41, the course is $24^{\circ} 45'$. Therefore the horizontal arc is $24^{\circ} 45'$.
Rem. true amp.	= $65^{\circ} 28'$ from N.		

In this and the following examples the nearest degree and minute to the declination, that can be found in the Traverse Table, is taken for the declination.

EXAM.

EXAM. II. Required the Sun's true amplitude in the lat. of $51^{\circ} 32' N$. when the Sun's declination is $20^{\circ} 56' S$.

By Logarithms.

As cof. lat.	= $51^{\circ} 32'$	0,20617
To radius	= R	10,00000
So sin. decl.	= $20 56$	9,55301
To sin. hor. arc	= $35 03$	9,75918
Add to	$90 00$ for S. decl.	
Gives true amp.	= $125 03$ fr. the N.	

By the Traverse Table.

To decl. $21^{\circ} 00'$, and dist. 100, the dep. is 35,8.
To lat. $51^{\circ} 30'$, and diff. lat. 35,8, the dist. is 57.
To dist. 100, and dep. 57, the course is $34^{\circ} 45'$. Therefore 35° may be taken for the horizontal arc sought.

EXAM. III. When the Sun's declination was $20^{\circ} 10' S$. what was his amplitude at the Cape of Good Hope, in lat. $34^{\circ} 15' S$?

By Logarithms.

As cof. lat.	= $34^{\circ} 15'$	0,08271
To radius	= R	10,00000
So sin. decl.	= $20 10$	9,53751
To sin. hor. arc	= $24 39$	9,62022
Which add to	$90 00$ for S. decl.	
Gives true amp.	= $114 39$ fr. the N.	

By the Traverse Table.

To decl. $20^{\circ} 15'$, and dist. 100, the dep. is 34,6.
To lat. $34^{\circ} 15'$, and diff. lat. 34,6, the dist. is 42.
To dist. 100, and dep. 42, the course is $24^{\circ} 45'$. Therefore 25° may be taken for the horizontal arc sought.

EXAM. IV. On what point of the horizon does the star Arcturus rise and set at Buenos Ayres, in lat. $34^{\circ} 35' S$?

By Logarithms.

As cof. lat.	= $34^{\circ} 35'$	0,08444
To radius	= R	10,00000
So sin. decl.	= $20 29$	9,54399
To sin. hor. arc	= $25 09$	9,62843
Which add to	$90 00$ for S. dec.	
Gives true amp.	= $115 09$ fr. the N.	

By the Traverse Table.

To decl. $20^{\circ} 30'$, and dist. 100, the dep. is 35,0.
To lat. $34^{\circ} 30'$, and diff. lat. 35,0, the dist. is 42,5.
To dist. 100, and dep. 42,5, the course is $25^{\circ} 15'$. Therefore the horizontal arc may be taken as 25 degrees.

SECTION IV.

To work an Azimuth.

27.

The true azimuth of a celestial object is its bearing from the north or south points of the horizon, when above it.

In the forenoon the azimuth is reckoned eastward, and in the afternoon westward.

The azimuth is usually estimated from the south, when to the southward of the east or west points of the horizon; and from the north when to the northward of those points.

The use of the azimuth is to find the variation of the compass, in order to correct the courses which the ship has steered.

28.

PROBLEM.

The latitude of the place, the declination of the object, and its altitude being known; required the true azimuth of that object.

SOLUTION.

When the latitude and declination are of the same name, let the co-declination be called A.

But when of contrary names, add the declination to 90 degrees, and call the sum A.

Let the difference between the co-lat. and co-alt. be called D.

Also, find the half sum and half difference of A and D.

Then write these four logarithms under one another.

Namely: The arith. comp. of the log. sine of the co-latitude.

The arith. comp. of the log. sine of the co-altitude.

The logarithmic sine of the foresaid half sum of A and D.

The logarithmic sine of the foresaid half diff of A and D.

Add these four logarithms together, and take half their sum, which seek among the sines for the corresponding degrees and minutes, and these being doubled will give the true azimuth required: from the north, in north latitudes, and from the south in south latitudes.

The working of an azimuth by logarithms, although as short as any numeral solution of this problem can be expected to be, has been thought one of the most tedious elements that enter into a common day's work: but by Gunter's scale, it may be readily done as follows, and sufficiently correct.

29.

To work an Azimuth by the Gunter's Scale.

Find the co-lat., co-alt., the half sum, and half difference, as above.

Then, On the scale of log. sines, set one point of the compasses on the half sum, extend the other point to the co-lat., observing whether the second point falls to the right or left of the first, and take the compasses off without altering their extent.

Set one point on the co-alt., and let the second point fall where it will (the same way it did before); there hold it, and open the compasses till the other point falls on the half difference, then take them off without altering their extent.

Now

Now set one point of the compasses on the brass pin at the beginning or right-hand end of the scale of versed sines (marked V. S.), turn the other point to the left, and observe what degrees and minutes in the versed sines it falls on; those degrees and minutes will be the azimuth, if the latitude is south: but if north, take them from 180° , and the remainder is the azimuth sought, reckoned in both cases from the north.

If the extent, when applied from the co-alt. to a fourth, should reach beyond the right-hand end of the scale, as will sometimes happen, then lay the Gunter flat on a board or table, and let the point rest on it in a line with the sines, and take the extent from thence to the half difference, and work as before.

These directions, with those in Book III. 84, 85, will remove all the seeming difficulties, that beginners may meet with, in working an azimuth by the Gunter's scale.

EXAM. I. *At sea, in latitude $40^\circ 38' N.$ in the afternoon, the Sun's altitude was observed to be $20^\circ 46'$, when his declination was $17^\circ 10' S.$: Required the Sun's true azimuth at that time.*

By LOGARITHMS.

The co-alt. is $69^\circ 14'$	Ar. co-log. fin. co-lat. = $49^\circ 22'$	0.11982
The co-lat. is $49 \quad 22$	Ar. co-log. fin. co-alt. = $69 \quad 14$	0.02917
	Log. fin. $\frac{1}{2}$ sum = $63 \quad 31$	9.95185
The diff. $D=19 \quad 52$	Log. fin. $\frac{1}{2}$ diff. = $43 \quad 39$	9.83901
Now $107^\circ 10' = A = 90^\circ$ & decl.	The sum of the four logs	19.93985
And $19 \quad 52 = D.$	Their $\frac{1}{2}$ sum gives $38^\circ 55'$	9.56992
$\begin{array}{r} 127 \quad 02 \quad 63^\circ \quad 31' = \frac{1}{2} \text{ sum.} \\ 2) \quad \underline{\hspace{1cm}} \\ 87 \quad 18 \quad 43 \quad 39 = \frac{1}{2} \text{ diff.} \end{array}$	The double is, $137 \quad 50$, which is the Sun's true azim. from the N. point of the horizon.	

By GUNTER'S SCALE.

On the sines, the extent from $63^\circ 31'$ to $49^\circ 22'$ will reach from $69^\circ 14'$ to a little more than 52° . Let the point rest there, and extend the other to $43^\circ 39'$; this extent will reach from the beginning of the versed sines to about 42° , which taken from 180 , leaves 138° for the azimuth from the N. point of the horizon, and is very near what was found by the logarithms.

EXAM. II. *What is the Sun's true azimuth in the latitude of $26^\circ 30' N.$ when his altitude in the forenoon is $24^\circ 28'$, and his decl. is $22^\circ 40' N.$?*

By LOGARITHMS.

The co-alt. is $65^\circ 32'$	Ar. co-log. fin. co-lat. = $63^\circ 30'$	0.04821
The co-lat. is $63 \quad 30$	Ar. co-log. fin. co-alt. = $65 \quad 32$	0.04086
	Log. sine $\frac{1}{2}$ sum = $34 \quad 41$	9.75514
The diff. $D=2 \quad 02$	Log. sine $\frac{1}{2}$ diff. = $32 \quad 39$	0.73200
Now $67^\circ 20' = A$, is 90° less decl.	The sum of the four logs	19.57621
And $2 \quad 02 = D.$	Their $\frac{1}{2}$ sum gives $37^\circ 52'$	9.78810
$\begin{array}{r} 69 \quad 22 \quad 34^\circ \quad 41' = \frac{1}{2} \text{ sum.} \\ 2) \quad \underline{\hspace{1cm}} \\ 65 \quad 18 \quad 32 \quad 39 = \frac{1}{2} \text{ diff.} \end{array}$	The double is, $75 \quad 44$, which is the Sun's true azim. from the N. point of the compass.	

By GUNTER'S SCALE.

On the log. fines, the extent from $34^{\circ} 41'$ to $63^{\circ} 30'$, will reach from $65^{\circ} 32'$ to some point beyond the right-hand end of the scale; let the point of the compasses rest there, and extend the other point to the fine of $32^{\circ} 39'$, and this extent will reach on the versed fines, from the beginning, or 0 deg. to $104^{\circ} 20'$, the azimuth from the south, nearly as found by logarithms.

EXAM. III. *At the island of St. Helena, in lat. $16^{\circ} 00' S$. the Sun's altitude was observed in the forenoon to be $30^{\circ} 22'$, when his declination was $22^{\circ} 58' S$.: What was the Sun's azimuth at that time?*

The co-lat. is $74^{\circ} 00'$	Ar. co-log. fine co-lat. = $74^{\circ} 00'$	0,01716
The co-alt. is $59^{\circ} 38'$	Ar. co-log. fine co-alt. = $59^{\circ} 38'$	0,06409
	Log. fine $\frac{1}{2}$ sum = $40^{\circ} 42'$	9,81431
	Log. fine $\frac{1}{2}$ diff. = $26^{\circ} 20'$	9,64698

Now $67^{\circ} 02' = A$, is 90° less decl.
And $14^{\circ} 22' = D$.

The sum of the four logs. 19,54254

Their $\frac{1}{2}$ sum, gives $36^{\circ} 12'$ 9,77127

Which doubled, is $72^{\circ} 24'$, for the Sun's true azim. from the south, or $107^{\circ} 36'$ from the N.

Or thus: The extent from $40^{\circ} 42'$ to $74^{\circ} 00'$ on the fines, will reach from the fine of $59^{\circ} 38'$ to a point beyond the limits of the scale; then the extent from that point to the fine of $26^{\circ} 20'$, will reach on the versed fines from 0 deg. to about $107^{\circ} 40'$, the azimuth from the north.

EXAM. IV. *On what point of the horizon, at the Cape of Good Hope, does the star Aldebaran bear, when its altitude is $22^{\circ} 25'$?*

The co-alt. is $67^{\circ} 35'$	Ar. co-log. fin. co-lat. = $55^{\circ} 45'$	0,08271
The co-alt. is $55^{\circ} 45'$	Ar. co-log. fin. co-alt. = $67^{\circ} 35'$	0,03412
	Log. fin. $\frac{1}{2}$ sum = $58^{\circ} 54'$	9,93261
	Log. fin. $\frac{1}{2}$ diff. = $47^{\circ} 05'$	9,86472

Now $105^{\circ} 59' = A$, is 90° , and decl.
And $11^{\circ} 50' = D$.

The sum of the four logs. 19,91416

Their $\frac{1}{2}$ sum gives $64^{\circ} 57'$ 9,95708

Which doubled, is $129^{\circ} 54'$, for the Sun's true azim. from the S. or $50^{\circ} 06'$ from the N.

Or thus: The extent from about 59° to about $67\frac{1}{2}^{\circ}$ on the fines reaches from about $55\frac{1}{2}^{\circ}$ to about 63° : then the extent from about 63° to about 47° , reaches from the beginning of the versed fines, to about 50° for the azimuth from the north.

These examples sufficiently shew, that an azimuth may be worked by the Gunter's scale, not only with great readiness, but also as accurately as the magnetic azimuth can be taken by the compass.

The manner of working amplitudes and azimuths has been pretty largely insisted on, in order to render them familiar to mariners; who, for the generality, esteem these operations very troublesome; and it is on this account that many writers have contrived various tables to remove the trouble complained of: but from a due consideration of what is here done, it is apprehended such tables will not hereafter be much wanted.

SECTION V.

30. *Of the Variation of the Compass.*

The *magnetic poles* are those points of the world, towards which the north and south ends of the needle in the sea compass are directed.

Magnetical meridians are imaginary lines, passing through the magnetic poles.

The *variation of the compass* is the difference between the bearings of the *true* and *magnetic* north poles; and is measured by an arc of the horizon contained between the true and magnetic north points of it.

The variation is named *east*, when the magnetic north point is to the eastward of the true north: but when to the westward, it is named *west* variation.

The magnetic amplitude of a celestial object is its bearing by the compass when in the horizon.

The magnetic azimuth of a celestial object is its bearing by the compass when above the horizon.

The variation is found by comparing the true and magnetic amplitudes or azimuths of celestial objects together.

The use of the variation is to correct the courses which a ship has steered by the compass.

31.

P R O B L E M.

*Given the true and magnetic amplitudes or azimuths of a celestial object:
Required the variation of the compass.*

S O L U T I O N.

Let the true and magnetic amplitudes or azimuths, be reckoned from the north; and named east when the observation is made in the forenoon; but west when made in the afternoon.

Then the difference between the true and magnetic amplitudes or azimuths, is the variation of the compass.

And is of the same name as the true amplitude or azimuth, if the true is greater than the magnetic: but when the true is less than the magnetic, the variation is of a contrary name to the true amplitude, or azimuth.

For, let *N* represent the true north point of the horizon, and the arc *NWO* the true amplitude or azimuth: it is evident, that if the arc *OWN*, representing the magnetic amplitude or azimuth, be less than *OWN*, then the magnetic north point of the compass will fall on the same side of the true north, that the amplitude or azimuth is on; but when greater, *n* falls on the contrary side. Plate XIV. Fig. 8.

EXAM.

EXAM. I. *The Sun was observed to rise 70° from the north by the compass, when his true amplitude was N. $81^{\circ} 45'$ E. : What was the variation, and which way ?*

True amplitude = $81^{\circ} 45'$ E.
Magnetic amplitude = $70^{\circ} 00'$
The variation = $11^{\circ} 45'$ E.

EXAM. II. *The Sun was observed by the compass to set WSW. when his true amplitude was N. $126^{\circ} 17'$ W. : Required the variation of the compass, and which way.*

True amplitude = $126^{\circ} 17'$ W.
Mag. amplitude = $112^{\circ} 30' = 10$ pts.
The variation = $13^{\circ} 47'$ W.

EXAM. III. *Suppose the Sun's true azimuth be N. $84^{\circ} 40'$ W. when his bearing was W. b. S. by the compass: Required the quantity and quality of the variation.*

True azimuth = $84^{\circ} 40'$ W.
Mag. azimuth = $101^{\circ} 15' = 9$ pts.
The variation = $16^{\circ} 35'$ E.

EXAM. IV. *When the Sun was observed to bear ESE. his true azimuth was found to be N. $88^{\circ} 46'$ E. : What was the quantity and name of the variation ?*

True azimuth = $88^{\circ} 46'$ E.
Mag. azimuth = $112^{\circ} 30'$
The variation = $23^{\circ} 44'$ W.

The manner of finding the variation being known, the courses may be corrected by the following rules.

32.

PROBLEM.

*Given the course set, and the variation of the compass :
Required the true course the ship steers.*

SOLUTION.

Let the person suppose himself looking the way the ship sails ; then the course steered by the compass must be altered as many degrees, or points and parts of a point, as the variation amounts to toward the right hand, if the variation be east ; but it must be altered the like quantity towards the left hand, if the variation be west.

EXAM. I. *Suppose the variation is $1\frac{1}{2}$ point W. ; to correct these courses, NNW. ; SW. $\frac{1}{2}$ W. ; SE. b. S. $\frac{3}{4}$ E. ; ENE. $\frac{1}{4}$ E.*

Courses set NNW. 2 pts.	SW. $\frac{1}{2}$ W. $4\frac{1}{4}$ pts.	SE. b. S. $\frac{3}{4}$ E. $3\frac{3}{4}$ pts.	ENE. $\frac{1}{4}$ E. $6\frac{1}{4}$ pts.
Variation Add $1\frac{1}{2}$ pts.	Subtr. $1\frac{1}{2}$ pts.	Add $1\frac{1}{2}$ pts.	Subtract $1\frac{1}{2}$ pts.
Cor. co. NW. b. N. $\frac{1}{2}$ W. $3\frac{1}{2}$ pts.	SW. b. S. 3.	SE. b. E. $\frac{1}{4}$ E. $5\frac{1}{4}$ pts.	NE. $\frac{3}{4}$ E. $4\frac{3}{4}$ pts.

EXAM. II. *The variation is 18° E. ; to correct the following courses.*

Courses set N.E. b. N. $= 33^{\circ} 45'$	S. b. E. $= 11^{\circ} 15'$	S.W. b. W. $= 56^{\circ} 15'$	NW. $= 45^{\circ} 00'$
Variation Add 18 00	Subtr. 18 00	Add 18 00	Subtr. 18 00
Cor. cour. N. 51 45 E.	S. 6 45 W.	S. 74 15 W.	N. 27 00

SECTION VI.

33. *Of finding the Ship's drift, or leeway.*

When a ship turns to windward, or is close hauled on a wind, she generally runs to the leeward of her intended course.

LEEWAY is the angle which the ship's real course makes with her intended course, occasioned by contrary winds, and a rough sea.

The leeway made by different ships, under the same circumstances of wind and sails, will be different; and even the same ship, when differently laden, and having more or less sail abroad, will make more or less leeway. However, the following precepts for allowing for the leeway have been generally given by English writers; they were first published by W. Jones, Esq. who had them from Mr. John Buckler.

34. *Allowances for Leeway.*

1st. When a ship is close hauled, has all her sails set, the water smooth, and a moderate gale of wind, she is then supposed to make little or no leeway.

2d. Allow one point, when it blows so fresh that the small sails are taken in.

3d. Allow two points, when the top-sails must be close reefed.

4th. Allow two points and a half, when one top-sail must be handed.

5th. Allow three points and a half, when both top-sails are to be taken in.

6th. Allow four points when the fore course is handed.

7th. Allow five points, when trying under the main-sail only.

8th. Allow six points, when both main and fore courses are taken in.

9th. Allow seven points, when the ship tries a hull, or all sails handed.

When the wind has blown hard on any point of the compass, and shifts to the opposite point, the ship will make less leeway than she did before.

But in all these cases respect must be had to the roughness of the sea, and the trim of the ship.

35.

P R O B L E M.

Given the place of the wind, the course set, and the leeway. Required the true course the ship makes.

RULE. Count the nearest way of the compass from the wind to the course set, and as many points and parts beyond as the leeway amounts to; and it gives the true course which the ship makes.

EXAM. I. *The wind NW. b. N. the course set NE. b. N. leeway 1 point: What is the course made good?*

The wind NW. b. N.

Course set NE. by N. = 3 points.

And the leeway = 1 point

True course NE. = 4 points.

Here, counting the nearest way in the compass from NW. b. N. to NE. by N. and one point farther for the leeway, because the wind drives her farther towards the east, will give NE. for the true course that the ship makes.

EXAM. II. *The wind SE. b. S. a ship is close hauled with her starboard tacks aboard, and both top-sails handed: What is her true course?*

The wind SE. by S.

Course set E. b. N. = 7 points.

Subtract leeway = $3\frac{1}{2}$ points.

True co. NE. by N. $\frac{1}{2}$ E. = $3\frac{1}{2}$ points.

The ship being close hauled, is supposed to be 6 pts. from the wind, and must be in the NE. quarter, being on her starb. tacks: then counting 6 pts. from SE. b. S. gives E. by N. 7 pts.; from which the leeway is to be taken.

SECTION

SECTION VII.

Of Instruments for taking Altitudes.

The altitude of the Sun, or any other celestial object, may be observed by instruments contrived after various ways; those only which are best adapted for use at sea, will be here considered.

Of DAVIS'S QUADRANT.

36. *The Description and Use.* Plate XIV. Fig. 9.

The instrument most in use at sea, until about the year 1740, is by us called DAVIS'S QUADRANT, and by foreigners the ENGLISH QUADRANT. It consists of two arches, making together ninety degrees, and is therefore called a quadrant. Those arches are fixed in the same plane, one above, and the other below a straight bar, the length of which is equal to the radius of the lower arch, and about three times the radius of the upper arch; and they are connected and supported by proper braces.

The upper, or, as it is commonly called, the GREATER ARCH usually contains 65 degrees, not subdivided into smaller parts; and the LESSER ARCH contains 25 degrees, which, on account of their larger size, are subdivided into smaller parts, and these, by the help of diagonal divisions, and 11 concentric circles, are usually subdivided into single minutes.

There are three pieces called vanes, so fitted to the instrument as to stand at right angles to its plane.

First, The HORIZON VANE is fitted to slip on the end of the bar or radius, close to the center of the two arches. In this vane there is a long slit, through which the horizon, that is, the line where the sky and water apparently meet, is to be seen.

Secondly, The SIGHT VANE, which is so fitted as to slide along the lesser arch of 25 degrees, having a sharp edge to cut the division it stands at; and in a line with this edge is a small hole, through which the horizon is to be seen through the slit in the horizon vane.

Thirdly, The SHADE VANE, which is fitted to slide on the greater, or 65 arch. The upper line of the shade cast by this vane is to fall on the edge of the slit in the horizon vane during the time of observation.

Instead of the shade vane there is generally used another, called the GLASS VANE, because it has a convex lens (or, as usually called, a burning glass) fitted to it, which collects the Sun's rays into a bright spot on the horizon vane.

AB, is the bar or radius. BC, the lesser or 25 arch. DE, the greater or 65 arch. *ab*, *cg*, *hi*, are braces which fix the arches to the radius, and strengthen the instrument. G the horizon vane. H the sight vane. F the shade or glass vane. $\odot$ FA a ray of the Sun. $\angle DAC$ a right angle, or 90° .

37. *To observe the Sun's altitude or zenith distance by Davis's Quadrant.*
See Plate XIV. Figure 9.

First, Put the horizon vane on to the end A of the bar AB; and let it go close to the shoulder at A. Set the shade or glass vane on the arch

DE to an even degree, about 10 or 15 degrees less than what the zenith distance is judged to be; and put the sight vane H about the middle of the arch BC: observing that the shade and sight vanes be thrust close to the backs of the arches.

Secondly, Turn your back to the Sun, hold the plane of the instrument in an upright position, look through the hole in the sight vane, and raise or lower the quadrant until the bright spot cast by the Sun through the glass vane, falls on the Θ in the line drawn through the slit in the horizon vane; then, if the horizon is seen through the slit in the horizon vane, even with the Θ , the quadrant will give the Sun's altitude or zenith distance at that time.

Thirdly, But if the sky appears through the slit instead of the horizon, slide the sight vane H higher, until the horizon coincides with the bright spot falling on Θ ; or if the sea appears instead of the horizon, slide the sight vane H lower, until the spot and horizon come together, and the observation at that time is made.

Fourthly, To the degrees between D and F add those between C and H, their sum gives the zenith distance: but the degrees between B and H, added to those between F and E, shew the altitude.

38. Now to find the latitude, the *meridional* altitude or *meridional* zenith distance of the Sun is wanted. Therefore begin some time before noon, and having taken an observation as above directed, wait a minute or two, and observe again; and if the sea appears through the horizon vane the Sun has got higher, therefore slide the sight vane lower, till the solar spot and horizon coincide; and thus continue observing at short intervals, until the sky appearing instead of the sea shews that the Sun has past the meridian; when this happens, let the vane stand as at the last alteration, and add the degrees in the greater arc to the degrees and minutes in the lesser, their sum gives the meridional zenith distance.

If instead of the bright solar spot, the upper border of the shade be made to fall upon the horizon line, at the time the horizon is seen through the slit in that line, then the sum of the arcs is the zenith distance of the Sun's upper edge or limb, to which add 16 minutes, and the sum is the distance of the Sun's center from the zenith *.

39. One great objection against this instrument is the trouble and time lost in sliding the sight vane up or down, which sometimes cannot be done without taking the quadrant from the eye, by which means an opportunity may be lost of making the observation. But this defect is removed by having an index or ruler fitted to the quadrant; one end of it moving round the center to which the horizon vane is fixed, and the other carrying the sight vane along the arch. By this contrivance the sight vane may be readily raised higher, or lowered, by the motion of the index about its center, without taking the instrument from the eye.

* This rule is given by most writers; but as the extremity of every shadow cast by the sun is penumbral, too faint at the very extremity to be perceptible, and so nearly dark before it is really so, that the limit of the penumbra cannot be distinguished, it is obvious that it cannot be proper for practice, where the observer must necessarily take the middle between the two: nothing must therefore be allowed for the Sun's semi-diameter.

40. There is another instrument, called a *FORE STAFF*, or *CROSS STAFF*, that has been long used at sea for taking the altitudes of celestial objects, particularly the stars. In using this instrument the observer holds one end of the staff, which is a three-feet rod, close to one side of his eye, and slides a transum or cross piece, which is in an upright position, along the staff, until one end of the cross touches the star, and the other end the horizon at the same time; then the division of the staff, which the cross stands against, is the altitude. But the many inconveniencies which attend the use of the cross-staff, make it now of little note, especially since the use of *Hadley's quadrant* is become more general; as this instrument far surpasses all others for observing altitudes and distances of celestial objects at sea, both in ease and accuracy.

Of HADLEY'S QUADRANT.

41.

The Description and Use.

Pl. XIV. Fig. II.

This instrument consists of the following parts:

I. The arch *BC*, which is generally an octant, or eighth part of a circle; but is more useful when it is a sextant, or sixth part of a circle.

II. The index *D*, with its *Vernier's scale*.

III. The speculum *E*.

IV. Two horizon glasses, *F* and *G*, with their adjusters.

V. Two skreens, *K*, *K*.

VI. Two sight vanes, *H*, *I*.

I. *Of the Octant.*

The octant consists of the two radius's or bars *AB*, *AC*; the arch or limb *BC*; and the two braces, *L*, *M*, which are to strengthen and prevent it from warping. Although the arch contains only the eighth part of the circumference of a circle, or 45 degrees, it is divided into 90 primary divisions, each of which stands for a degree; they are numbered 0, 10, 20, 30, &c. to 90, beginning at each end of the arch for the convenience of numbering both ways, either for altitudes or zenith distances. Every degree is subdivided into two or three parts, and these again into single minures, either by diagonals, or *Vernier's method*, which is better.

II. *Of the Index.*

The index *D* is a flat bar, moveable round the center of the instrument; that part of the index which slides over the graduated arch *BC*, has either a sharp edge to cut the diagonal divisions, when the limb is so divided, or has *Vernier's scale* on it.

From the bottom of the index a piece of brass turns up against the back of the instrument, with a screw in it, serving to fasten the index against any division.

When the index is moved along the arch, it should be taken hold of by the bottom part, and not by the middle,

The principles, upon which the Vernier's scale depends, were shewn in Book V. Art. 219 ; but it may be proper to add some general directions in this place, by which learners may be enabled to read the degrees and minutes shewn by the index.

The generality of Hadley's quadrants are of 15 or 18 inches radius, and have each degree on its limb divided into three parts, of 20 minutes each. The breadth of the Vernier's scale is therefore equal to 7 degrees ; and as these seven degrees are divided into 21 parts on the limb, each of 20 minutes ; the scale is divided into 20 equal parts : consequently each division on the scale is larger than each division on the limb by $\frac{1}{20}$ th part of a division on the limb, or $\frac{1}{20}$ th of 20 minutes ; that is, each division on the scale exceeds each on the limb by 1 minute of a degree : consequently, if any one division of the Vernier's scale stands against one of the divisions on the limb, no other division on the scale can coincide with a division on the limb.

Now the middle line of the index D, which is the moveable radius of the quadrant, is the index, or pointer, of the Vernier's scale, and is usually its middle line ; there being 10 divisions, or minutes, on each side, numbered 5, 10, to the right, and 15, 10, to the left ; that is, the first 10 minutes of the scale is reckoned in order from the middle line or index to the right ; and the latter 10 minutes is to be reckoned from the left-hand end of the scale toward the right, and ends at the middle line, where the others began.

Suppose the middle line, or index of the Vernier stood against 48° , and somewhat more than one subdivision on the arch of the instrument. Examine, first towards the right hand of the scale, if any of its divisions stand against a division on the arch ; and suppose that the 7th division from the middle one is found to do so, these seven must be added to what the middle line on the Vernier stood beyond on the arch ; that is, to $48^\circ \frac{1}{3}$, or $48^\circ 20'$, and the whole will be $48^\circ 27'$ that the index of the instrument stood at on the arch. But if none of the right-hand divisions stand against a division on the arch, examine those on the left-hand, beginning at the extreme one, and proceeding toward the middle ; and let the 16th division be that which coincides with a division on the limb (for some one will) ; then those 16 added to $48^\circ 20'$ make $48^\circ 36'$ for what the index stood at. A magnifying glass, or double convex lens of a short focus, will assist the observer in distinguishing that division on the Vernier which coincides with, or stands against a division on the arch.

III. *Of the Speculum.*

The speculum is a flat piece of glass, quicksilvered on one side like a common looking-glass, and fixed to the index by means of a brass frame, directly over the center of it ; its surface coinciding nearly with the first division of the Vernier, and exactly perpendicular to the plane of the instrument. The position of its surface must therefore alter as the index turns on its center.

The use of the speculum is to receive the rays from the object observed, and reflect them on the horizon glasses,

IV. *Of*

IV. *Of the Horizon Glasses.*

These are small pieces of looking-glass placed on one of the radii, the face of one of them being parallel, and that of the other perpendicular to the speculum when the index stands at 0; they receive the reflected rays of observed objects from the speculum, and transmit them to the eye of the observer.

The glass F has only its lower part quicksilvered, and set in brass work: the upper part being left transparent, that the horizon may be seen through it.

In the middle of the glass G is a transparent slip, through which the horizon is to be seen.

Both of these glasses are so mounted, as to have their positions set truly by their adjusters at the back, should the frame of the instrument be warped.

V. *Of the Skreens.*

These are two pieces of coloured glass set in frames, to prevent the Sun's rays from hurting the eye during the time of observation. When they are used with the glass F, they are to be where the figure shews them; but when used with the glass G, they are to be set at their hole *r* above G.

VI. *Of the Sight Vanes.*

That at H is used with the glass G in back observations: and the sight vane I, which has two holes, is used with the glass F in fore observations.

For with this instrument an observation may be made with the face turned from the object, which is called a back observation; or with the face turned toward the object, which is called a fore observation: but before any observation is attempted, the instrument should be examined to see if it is fit for use.

To rectify or adjust Hadley's Quadrant.

42.

I. *For the fore Observation.*

Bring the index D close to the button *b*, that the middle of the Vernier's scale may stand against 0 degrees. Hold the plane of the instrument vertical with the arch downward; look through the right-hand hole in the vane I, and direct the sight through the transparent part of the glass F to the horizon. Now if the horizon line, seen both in the quicksilvered part, and through the transparent part, should coincide, or make one straight line, the glass F is truly adjusted. But if one of the horizon lines stand above the other, slacken the screw in the middle of the lever, behind the glass E, and turn the screw at the end of the lever backward or forward, as there is occasion, until the horizon lines coincide; fasten the screw in the middle of the lever, and then the horizon glass is adjusted.

43. II.

43.

II. *For the back Observation.*

Turn the button *b* on one side, find the dip of the horizon on your height above the water in the following table (Art. 55.) and set the middle line of the index *D* as many minutes before 0 degrees, as there are in twice that dip. Hold the plane of the instrument vertically, with the arch downward; look through the hole in the vane *H*, and if the horizon line, seen through the transparent slit in the glass *G*, coincide with the image of the horizon seen in the quicksilvered part of the same glass, then the glass *G* is in its proper position. If not, slacken the screw pin in the middle of the lever, behind the glass *G*, and, looking through the vane *H* as before, turn the screw at the end of the lever backward or forward, as it is wanted, until the horizon lines coincide; then tighten the middle screw, and the glass *G* is adjusted. In setting this glass by the opposite horizon, the head should be held a little backward, not to intercept the light from behind. The horizon seen from behind will be inverted; that is, the water will appear above, and the sky below: if the two horizon lines cross one another, the instrument is not held upright.

To take the Sun's Altitude with Hadley's Quadrant.

44.

I. *By the fore Observation.*

Fix the screens *K* above the horizon glass *F*, using either or both of them, according to the strength of the Sun's rays, by turning one or both of the frames of these glasses close against the plane or face of the instrument; then the face being turned towards the Sun, hold the quadrant by the braces *L*, *M*, or by either radius, as is found most convenient, so as to be in a vertical position with the arch downward; put the eye close to the left-hand hole in the vane *I*; look at the horizon through the transparent part of the horizon glass *F*; at the same time, move the index *D* with the left-hand, until the image of the Sun, seen in the quicksilvered part, falls in with the line of the horizon, taking either the upper or under edge of the solar image. Swing your body gently from side to side, and if that edge of the Sun which is observed touch the horizon line like a tangent, without cutting it, the observation is well made: and the degrees on the arch, reckoned from that end next your body, give the altitude of that edge of the Sun which was brought to the horizon.

If the lower edge was observed, then 16 minutes added to the said degrees, give the altitude of the Sun's center; but if the upper edge was used, the 16 minutes must be subtracted.

45.

II. *By the back Observation.*

Put the stem of the screens *K* into the hole next the horizon glass *G*, using them as before said, according to the strength of the Sun's rays. Then the back being turned to the Sun, hold the instrument by the radius *C* and brace *L*, in a vertical position with the arch downward; put the eye close to the hole in the vane *H*, look for the horizon through

through the transparent slit in the glass G; with the right-hand move the index D, until the image of the Sun, seen in the quicksilvered part of the glass G, stands in the horizon line, seen through the transparent slit, using either the upper or under edge of the Sun, as is most convenient. Swing your body gently to the right and left, to try if the Sun's edge runs along the horizon; if it does, the observation is well made, and the degrees reckoned from that end of the arch farthest from your body, will give the altitude of that part of the Sun which was observed.

If the Sun's lower edge was observed, then 16 minutes subtracted from the said degrees, will give the altitude of the Sun's center; but if the upper edge was observed, then 16 minutes are to be added.

In either of these observations, if the altitude of the center could be observed, there would then be no need of using the 16 minutes.

46. The fore observation is rather most convenient, especially in great altitudes, because there is a much larger scope above and below the altitude wanted, than there is in the back observation, which, on account of the obliquity of the speculum and horizon glass, is more contracted in its use. And indeed the back observations need never be used for the Sun, when there is a clear horizon forward, or under the Sun: when this is hazy and ill defined, it is best to use the back observation, if the horizon is clear that way; it is proper, therefore, that the horizon glass G should be always in readiness, by having it well adjusted; and because the former method is not readily attained by beginners, we shall annex another somewhat more convenient.

47. *Another way to adjust for the back Observation.*

Take the altitude of the lower edge of the Sun by the fore observation, as near to noon as can be; then put the skreens into the hole near the vane H, and turning your back to the Sun, and holding the instrument properly, taking care not to move the index, look for the horizon line through the transparent slit of the glass G; and if the horizon line touches the upper edge of the Sun's image in the glass G, it is properly adjusted: if they do not touch, turn the glass by the lever behind it, till they do.

This operation must be done quickly, before the Sun sensibly alters in altitude; and may be frequently repeated to make the fore and back observations agree.

To take the Altitude of a Star by Hadley's Quadrant.

48. I. *By the fore Observations.*

Look directly up at the star through the vane I, and transparent part of the glass H, the index D being close to the button b; then will the image of the star, by reflection, be seen in the silvered part right against the star, seen through the other part. Move the index forward, and as the image descends, turn the quadrant round its center, keeping it all the time in a vertical position, and the image of the star on the silvered part

part of the horizon glass, till it comes down to the horizon seen through the transparent part ; and the observation is made.

49. If the altitude of the star is pretty great, some other stars, beside that wanted, may appear by reflection from the great speculum, on the horizon glass G ; these will dance with the motion of the instrument, but the true star will remain at rest about the middle of the glass, and so the others cannot be mistaken for it.

For the principles of the construction see the Appendix.

50. Hadley's Quadrants, within a few years past, having been applied to take the observations necessary for finding the longitude at sea, it has been found that such observations required a degree of accuracy, of which the instruments constructed in the common way were not capable : and expert mariners having complained of these defects, different workmen have applied sundry articles to the quadrants to remedy the inconveniencies complained of ; some of which follow.

1st. A screw to the lower end of the index, to regulate its motion when brought by the hand to a division shewing nearly the contact required ; and a magnifying glass to read off the divisions shewn on the limb by the Vernier.

2d. A small tube, or telescope, instead of the sight vanes, to direct the line of sight parallel to the plane of the quadrant ; which tube is to be screwed into a ring fixed to a square stem that slides in the socket made for the sight-vane, and by the help of a screw at the back of the quadrant this stem may be raised or lowered, so as to move the axis of the telescope to point to any part of the horizon glass which is judged fittest for the observation.

3d. The arch has also been extended from an octant to a sextant, or the sixth part of a circle ; by which means angles exceeding 90 degrees may be observed ; and such angles are often wanted in taking the angular distance between the Moon and Sun, or Moon and Star. Also, for the convenience of holding the instrument easily in such observations, a stout handle is fixed to the back, which is a very necessary addition.

4th. The speculum being liable, in the ordinary way of fitting it, to be bent ; and consequently the same observation would have different measures, according as the object happened to be reflected from different parts of the speculum ; this has been lately rectified by a new manner of setting the speculum in its frame.

5th. A new method of adjusting the glasses for the back observation has lately been discovered, very accurate in principle, and ready in practice, by the ingenious Mr. *Peter Dollond*, Optician to his Majesty ; who also thought of the method of preventing the index speculum from being bent in its frame. By his adjustments, angles of any magnitude under 180 degrees may be taken ; viz. by the fore observation all under 120°, with a sextant ; and by the back observation, all between 90 and 180 degrees.

6th. Although Mr. Hadley at first directed that the line of sight should be parallel to the plane of the instrument ; and for placing and preserving it so, proposed, that two parallel wires should be fixed in the telescope parallel to the plane of the quadrant, and that the contact

tact of the objects should be observed in the middle between the two wires ; yet these circumstances not being sufficiently attended to, the two parallel wires had been neglected in fabricating the instrument ; these two parallel wires are now replaced in the focus of the eye-glass, so as to divide the diameter of the field of view into three equal parts ; and when the telescope is adjusted parallel to the plane of the instrument, it will remain so during the observation.

7th. As every glass mirror has two reflections, *viz.* one from the face, and one from the silvered back surface, these double reflections cause not only some confusions among the reflected rays, but considerable errors in the observations, if the face and back of the glass be not parallel planes : and as none of these can happen from a plane mirror which has but one reflection, the upper part of the index speculum is now made with its back rough ground and blacked ; by this means the rays only which fall on its face will be reflected ; and these are found sufficient when the object observed is tolerably bright ; but when it is otherwise, the object may be observed from the lower part of the speculum, which is silvered ; the line limiting these two parts is parallel to the plane of the quadrant. These two improvements were directed by the Rev. Dr. Maskelyne, Astronomer Royal.

The methods, by which these several adjustments are to be made, together with some other particulars relating to the use of the instrument, are fully treated of in the book which accompanies the sale of Mr. Dollond's quadrants.

51.

To make an Artificial Horizon.

One great inconvenience that mariners have to struggle with at sea, is the frequent want of an horizon. For though the atmosphere may be clear enough to give a view of the Sun or other objects, at the height of 10 or 12 degrees and upwards, yet all below that height is often so hazy as to hinder a distinct sight of the horizon ; and consequently an observation made at such a time cannot have the desired correctness. And although water in a vessel will have its surface horizontal, and an observation may be made on the image of the Sun, seen in it when that water is perfectly still, yet the tremulous motion of its surface, from the least wind or motion of the ship, prevents this expedient from being generally used at sea ; and therefore many methods have been proposed ; among which *Serfon's* whirling Speculum, or Top, was, for a while, thought a proper instrument, but it has been found imperfect. Some artists use the following method :

Into a wooden, or iron, circular box, of about $2\frac{1}{2}$ or 3 inches diameter, and about $\frac{1}{2}$ inch deep, pour about a pound or more of quicksilver ; and on this lay a metal speculum, or piece of plain glass, the diameter of which is about $\frac{1}{3}$ of an inch less than that of the box ; this will float in the quicksilver, and shew the image of the Sun very steady. This apparatus being slung in jimbals will preserve a tolerable good horizon.

The speculum, or glass, should be homogeneous, and have parallel sides. There are some workmen, who can work the two planes of a piece of glass, so that they should be demonstratively parallel.

Or the fine surface of the quicksilver will do of itself, when the motion is not great.

In all observations made with these artificial horizons, a piece of coloured glass should be fixed before the sight vane, to preserve the eye; and the screens K may be taken off.

Corrections of the apparent or observed Altitude.

In observations of the Sun, it is usual to observe his upper or lower edge; to which his semidiameter being applied, gives the apparent place of the center. For this purpose, among the tables, page 255, is one shewing the Sun's semidiameter for every ten days throughout the year; as this is constantly altering with his distance from the Earth: but it is generally reckoned sufficiently accurate to allow 16 minutes for the Sun's semidiameter.

Every altitude observed at sea must be corrected: two corrections are common to the center of every object; and three to the Moon.

52.

I. THE DIP OF THE HORIZON.

The observer's eye being raised above the level of the sea, he sees an horizon below the level of the true one; and consequently the instrument gives an altitude too great, when a fore observation is used; and too small, with a back observation, unless the latter of the two methods for adjusting the back horizon glass be used.

As this error depends on the height of the eye above the water, and that on the size of the ship; a table of these corrections to different elevations has been computed and inserted for ready use. The principles upon which these computations depend are given in the Appendix to this IXth Book.

• 53.

II. THE REFRACTION.

The vapours in the atmosphere cause celestial objects to appear higher, or with greater altitudes, than they really have. These refractions, which are greatest at the horizon, and diminish in quantity as the altitudes increase, have been collected by eminent astronomers, and are here disposed of in the following table; the apparent altitude, above the true horizon, is to be diminished by the quantity of the refraction on that altitude.

For the principles, see the Appendix.

54.

III. PARALLAX.

From the explanation of parallax, at Art. 66. B. V. it is evident, that the Moon, when seen at the same time from the surface and center of the Earth, will not appear in the same place in the heavens; and this arises from the semidiameter of the earth bearing a sensible proportion to the distance between the Earth and Moon, which on a mean is about $\frac{1}{80}$, a quantity that considerably affects the observations on that planet; and therefore must be allowed for. But the distance of the Moon from the Earth constantly altering, between the Apogee and Perigee, the parallax also will be continually altering. The Moon's horizontal parallax, which lies between the limits of 53 minutes and 62 min. is given in the Nautical Almanac for every twelve hours throughout the year; which

which being known, her parallax to every two degrees of altitude, and every minute of horizontal parallax, may be found in the following table :

55. TABLES for correcting the observed ALTITUDES of CELESTIAL OBJECTS.

The semi-diam. of the Sun.			Dip. of Horizon.		Refractions of the Sun, Moon, and Stars, in Altitude.							
Day of month.	Sun's semi-diam.	Day of month.	Alt. of Eye.	Dip. of Hor.	App. Alt.	Ref.	App. Alt.	Ref.	App. Alt.	Ref.	App. Alt.	Ref.
	M. S.		feet.	M. S.	Deg.	M. S.	Deg.	M. S.	Deg.	S.	Deg.	S.
Jan. 1	16 19	31	5	2 8	2	18 35	16	3 17	35	81	54	41
10	16 19	21	8	2 42	2½	16 24	17	3 4	36	78	56	38
20	16 18	11	10	3 1	3	14 36	18	2 54	37	76	58	35
Feb. 1	16 17	Dec. 1	12	3 18	3½	13 6	19	2 44	38	73	60	33
10	16 15	21	15	3 42	4	11 51	20	2 35	39	70	62	30
20	16 13	11	18	4 3	4½	10 48	21	2 27	40	68	64	28
Mar. 1	16 11	Nov. 1	20	4 16	5	9 54	22	2 20	41	65	66	25
10	16 8	21	25	4 46	5½	9 8	23	2 14	42	63	68	23
20	16 6	11	30	5 14	6	8 28	24	2 7	43	61	70	21
Apr. 1	16 2	Oct. 1	35	5 39	6½	7 51	25	2 2	44	59	72	18
10	15 59	21	40	6 2	7	7 20	26	1 56	45	57	74	16
20	15 57	11	45	6 24	8	6 29	27	1 51	46	55	76	14
May 1	15 54	Sept. 1	50	6 44	9	5 48	28	1 47	47	53	78	12
10	15 52	21	55	7 4	10	5 15	29	1 42	48	51	80	10
20	15 51	11	60	7 23	11	4 47	30	1 38	49	49	82	8
June 1	15 49	Aug. 1	65	7 41	12	4 23	31	1 35	50	48	84	6
10	15 48	21	75	8 16	13	4 3	32	1 31	51	46	86	4
20	15 47	11	85	8 48	14	3 45	33	1 28	52	44	88	2
30	15 47	July 1	100	9 33	15	3 30	34	1 24	53	43	90	0

56. TABLES of the MOON'S PARALLAX in ALTITUDE.

Art. obf. D	Horizontal parallaxes.											Art. obf. D.	Horizontal parallaxes.											Augmentation of the D's semi-diam.	
	53	54	55	56	57	58	59	60	61	62	53		54	55	56	57	58	59	60	61	62	Moon's Alt.	Aug. S. diam.		
Deg.											Deg.														
1	53	54	55	56	57	58	59	60	61	62	50	34	35	35	36	37	37	38	39	39	40	0	0		
7	53	54	55	56	57	58	59	60	61	62	52	32	33	34	34	35	36	36	37	38	39	5	1		
12	52	53	54	55	56	57	58	59	60	61	54	31	32	32	33	33	34	35	35	36	37	10	3		
14	51	52	53	54	55	56	57	58	59	60	56	29	30	31	31	32	32	33	34	34	35	15	4		
16	51	52	53	54	55	56	57	58	58	59	58	28	29	29	30	30	31	31	32	32	33	20	6		
18	50	51	52	53	54	55	56	57	58	59	60	26	27	27	28	28	29	29	30	30	30	25	7		
20	50	51	52	53	54	54	55	56	57	58	62	25	25	26	26	27	27	28	28	29	29	30	8		
22	49	50	51	52	53	54	55	56	56	57	64	24	24	24	24	25	25	26	26	27	27	35	9		
24	48	49	50	51	52	53	54	55	56	57	66	22	22	22	23	23	24	24	24	25	25	40	10		
26	47	48	49	50	51	52	53	54	55	56	68	20	20	21	21	21	22	22	22	23	23	45	11		
28	47	48	49	49	50	51	52	53	54	55	70	18	18	19	19	19	20	20	20	21	21	50	12		
30	46	47	48	48	49	50	51	52	53	54	72	17	17	17	17	18	18	18	18	19	19	55	13		
32	45	46	47	47	48	49	50	51	52	53	74	15	15	15	15	16	16	16	16	17	17	60	14		
34	44	45	46	46	47	48	49	50	51	52	76	13	13	13	14	14	14	14	14	15	15	65	15		
36	43	44	44	45	46	47	48	48	49	50	78	11	11	11	12	12	12	12	12	13	13	70	15		
38	42	43	43	44	45	46	46	47	48	49	80	9	9	10	10	10	10	10	10	11	11	75	16		
40	40	41	42	43	44	44	45	46	47	48	82	7	7	8	8	8	8	8	8	9		80	16		
42	39	40	41	42	42	43	44	45	45	46	84	6	6	6	6	6	6	6	6	7		85	16		
44	38	39	40	40	41	42	42	43	44	45	86	4	4	4	4	4	4	4	4	4		90	16		
46	36	37	38	39	40	40	41	42	42	43	88	2	2	2	2	2	2	2	2	2					
48	35	36	37	37	38	39	39	40	41	42	90	0	0	0	0	0	0	0	0	0					

SECTION VIII.

Of Comparing and Correcting Time.

57.

PROBLEM I.

Given the estimated account of the ship's longitude from London; to find the corresponding times at the ship, and at London.

RULES.

Let the given time be always reckoned from the preceding noon; and turn the degrees in the difference of longitude into time. (V. 133)

I. Then east diff. long. in time, subtracted from the ship's time, gives Lond. time, P. M. from the noon used.

And east diff. longitude in time, added to London time, gives the ship's time, P. M. from the noon used.

Note, If it be necessary to borrow 24^h , the London time will be on the day preceding the given one.

Or, if the Sun exceed 24^h , the excess above 24^h is the ship's time on the following day.

II. West diff. longitude in time, added to the ship's time, gives Lond. time, for the noon used.

Or, The excess above 24^h , is Lond. time on the following day.

And west. diff. long. in time, subtracted from Lond. time, gives the ship's time from the noon used; or on the preceding day, if 24^h were borrowed.

EXAMPLES.

I. *What London time answers to a ship's noon, at a place 4 hours to the eastward of London?*

Here ship's time is 24^h from preceding noon.

Then $24^h - 4^h = 20^h$ P. M. London time, on the day before.

Or, Ship's noon answers to 8 o'clock morning at London.

III. *What London time is it, when it is noon at a ship 5h. to the west of London?*

0^h P. M. + 5^h W. = 5^h P. M. at London.

II. *When it is 8 o'clock in the morning at London, what is the corresponding time at a ship 4h. to the eastward?*

Here 8 o'clock morning, is 20^h P. M. from noon of preceding day.

Then 20^h P. M. + $4^h = 24^h$ P. M. ship's time.

Or, 8 o'clock in the morning at London answers to noon in the ship.

IV. *When it is 5h. P. M. at London, what hour is it at a ship 5h. W. of London?*

5^h P. M. - 5^h W. = 0^h P. M. or noon in the ship.

V. *What*

V. *What London time answers to 2h. 38m. P.M. at a ship 22 deg. to the east of London?*

22° E. makes 1^h 28^m. (V. 133)
Then 2^h 38^m P.M. — 1^h 28^m E.
= 1^h 10^m P.M. at London.

VII. *What time is it at London, when a ship 40° W. of London reckons it 3h. 20m. P.M.*

40° W. = 2^h 40^m W. (V. 133)
Then 3^h 20^m P.M. + 2^h 40^m W.
= 7^h 0^m P.M. London.

IX. *What London time answers to 5h. 26m. P.M. at a ship 120° E. of London?*

120° E. makes 8^h E. (V. 133)
Then 2^h 26^m P.M. — 8^h E. = 21^h 26^m P.M. the preceding day.
Or, 9^h 26^m in the morn. at Lond.

XI. *What London time answers to 5h. 42m. P.M. in a ship 110° W. of London?*

110° W. = 7^h 20^m W. (V. 133)
Then 5^h 42^m P.M. + 7^h 20^m W.
= 13^h 2^m P.M. Or 1^h 2^m in the morning at London.

XIII. *A ship 28° 30' E. of London, reckons 7h 42m in the morning: what hour is it at London?*

28° 30' E. = 1^h 54^m E.
Then 7^h 42^m P.M. — 1^h 54^m E.
= 17^h 48^m P.M.
Or, 48^m after 5 in the morning.

XV. *What London time answers to 6h. 45m. in the morning, at a ship 66° W. of London?*

66° W. = 4^h 24^m W.
Then 18^h 45^m P.M. + 4^h 24^m W.
= 23^h 9^m P.M.
Or, 11^h 9^m in the morning at London.

VI. *When it is 1h. 10m. P.M. at London, what time is it at a ship 22° E. of London?*

22° E. makes 1^h 28^m. (V. 133)
Then 1^h 10^m P.M. + 1^h 28^m E. =
2^h 38^m P.M. at the ship.

VIII. *When it is 7h. P.M. at London, what ship's time is it 40° W. of London?*

40° W. = 2^h 40^m W. (V. 133)
Then 7^h P.M. — 2^h 40^m W. = 3^h 30^m P.M. ship.

X. *When it is 9h. 26m. morning at London, what ship's time is it at 120° E. of London?*

120° E. makes 8^h E. (V. 133)
Then 2^h 26^m P.M. + 8^h E. = 29^h 26^m P.M. or 5^h 26^m on the following day.

XII. *What is it at a ship 110° W. of London, when it is 1h. 2m. in the morning at London?*

110° W. = 7^h 20^m W. (V. 133)
Then 1^h 2^m P.M. — 7^h 20^m W.
= 5^h 42^m P.M. ship.

XIV. *When it is 5h. 48m. morning at London, what hour is it at a ship 28° 30' E. of London?*

28° 30' E. = 1^h 54^m E.
Then 5^h 48^m P.M. + 1^h 54^m E.
= 19^h 42^m P.M. ship.
Or, 7^h 42^m in the morning.

XVI. *When it wants 51m. of noon at London, what hour is it at a ship 66° W. of London?*

66° W. = 4^h 24^m W.
Then 23^h 9^m P.M. — 4^h 24^m W.
= 18^h 45^m P.M.
Or, Time at the ship is 6^h 45^m morning.

XVII. *When it is 4^h. 26^m. morning, at a ship 98° 45' E. of London: what hour is it there?*

98° 45' E. = 6^h 35^m E.
Then 16^h 26^m P. M. — 6^h 35^m E.
= 9^h 51^m P. M. at London.

XIX. *What London time answers to 10^h. 40^m. morning, at a ship 160° W. of London?*

160° W. = 10^h 40^m W.
Then 22^h 40^m P. M. + 10^h 40^m W. = 33^h 20^m P. M. or 9^h 20^m P. M. at London, on the following day.

XVIII. *What hour is it at a ship 98° 45' E. of London. when it is 9^h. 51^m. P. M. at London?*

98° 45' E. = 6^h 35^m E.
Then 9^h 51^m P. M. + 6^h 35^m E. = 16^h 26^m P. M.
Or, 4^h 26^m morning at the ship.

XX. *When it is 9^h. 20^m. P. M. at London, what hour is it at a ship 160° W. of London?*

160° W. = 10^h 40^m W.
Then 33^h 20^m P. M. — 10^h 40^m W. = 22^h 40^m ship; or, 10^h 40^m morning at the ship, on the preceding day.

These twenty examples have been introduced, because experience hath shewn that a variety is necessary to most beginners.

58.

P R O B L E M I I.

To find the apparent time at sea, and thereby to regulate, or compare, the going of a watch.

I. *By equal Altitudes.* (V. 215, 297.)

The ship lying by, let the Sun's altitude be taken at any time in the forenoon, 3, 4, or 5 hours distant from noon, set down that time and altitude. In the afternoon, wait until the Sun has the same altitude exactly (the index of the quadrant being already set to the morning altitude) and note down that time; then the half sum of these two times is the apparent time shewn by the clock or watch, when the Sun was on the meridian of that place.

If it were wanted to reduce the apparent time to mean time,

Seek in the Nautical Almanack * for the given day, and take out the equation of time; which applied, as its title directs, to the apparent time, gives the mean time. Astronomical tables are usually fitted to mean time.

As it is possible that an altitude taken in the morning cannot have a corresponding one in the evening by the interposition of clouds; it is best to take several in the forenoon; in order to have a greater probability of securing a corresponding altitude in the afternoon; and if several observations of equal altitudes can be made on both sides of the meridian, it will be best to find the noon to each pair, and take a mean of all the noons thus found for the true one.

* The Nautical Almanack is published annually, under the direction of the Commissioners of Longitude, which Almanack every skilful mariner should have with him at Sea.

If equal altitudes are taken within six weeks or two months of an equinox, it will be proper to make an allowance for the change in the Sun's declination between the forenoon and afternoon observations, as is shewn in Book V. Articles 217, 297.

If there is reason to suspect, that the watch gains or loses considerably in a day, other sets of observations should be taken on successive days, by which the daily variation of the watch may be found, and allowed for.

EXAM. I. *May 20th, 1772, at 8^h 40^m forenoon, and at 3^h 16^m afternoon, by my watch, the Sun had equal altitudes: required the going of the watch?*

Add together	12 ^h 0 ^m
	+ 8 40
	+ 3 16

Take the half sum	23 56

Rem. noon by the watch	= 11 58
------------------------	---------

Apparent noon	= 12 0

Watch too slow	2 min.

May 20th. ap. noon	11 58
--------------------	-------

Equal time subtr.	4

Mean noon, by watch	11 54

EXAM. II. *March 18, 1772, being in latitude 49° N. at 8^h 10^m 58^s forenoon, and at 3^h 58^m 34^s afternoon, the Sun had equal altitudes: how did the watch go?*

Add together	12 ^h 0 ^m 0 ^s
	+ 8 10 58
	+ 3 58 34

Take half the sum	24 9 32

Gives the middle time	12 4 46
-----------------------	---------

Corr. on mid. time	19

Noon by watch	12 4 27
---------------	---------

Apparent noon	12 0 0

Watch too fast	4 27

March 18th ap. noon	12 4 27
---------------------	---------

Equa. time add	8 4

Mean noon, by watch	12 12 31

II. By an observation of the Sun's altitude.

1st. At a convenient time take the altitude of the Sun's upper or lower limb, which correct for the semidiameter, dip, and refraction; by which the correct zen. dist. of the Sun's center will be known.

2d. At the time of the observation find the Ship's lat. and long. by account; (VIII. 60) and correct the Sun's decl. for the day, by the diff. of long. and time from noon; and thereby get the true polar distance.

3d. With the co-latit. polar-dist. and zen. dist. find the hour angle: (V. 152.)

Which turned into time, shews the app. time when the obser. was made.

III. By an observation of a Star's altitude.

1st. Correct the observed altitude by the dip and refraction. (55.)

2d. Find the ship's latitude and longitude by account. (VIII. 60.)

3d. Seek the Star's decl. or polar dist. and its right ascension. (V. 312.)

4th. With the co-lat. polar dist. and zen. dist. find the hour angle. (V. 155.)

5th. Apply the hour angle (in time) to the star's right ascension, and it gives the right ascension of the mid-heaven. (V. 133.)

6th. Find the Sun's right ascension to the place and time. (V. 288.)

7th. The difference between the Sun's right ascension and that of the mid-heaven is the apparent time of the observation. Regulate the watch by the apparent time thus found.

The logarithmic work for the Sun in Art. 2d, or for the star in Art. 3d, may be performed by either of the following rules.

RULE I. Let the diff. between the co-lat. and polar dist. be called D. Find the half sum, and half diff. of the zen. dist. and D.

Then, To the ar. co. of the log. sines of the co-lat. and polar dist. Add the log. sines of the said half sum and half diff.

And Half the sum of these four logs. is the log. sine of $\frac{1}{2}$ the hour angle.

RULE II Add together the co-alt. co-lat. and polar dist. call the half sum A.

Let the diff. between the half sum A and co-alt. be called D. Then, To ar. co. of the log. sines of the co-lat. and polar dist. Add the log. sines of A and D.

And Half the sum of these 4 logs. is the log. co-sine of $\frac{1}{2}$ the hour angle.

EXAMPLES.

I. *January 26, 1780, at 2^h 56^m 56^s P. M. by my watch, the true alt. of the sun's center was 9° 44', the ship's lat. 51° 42' N. long. 33° W. Required the error of the watch?*

Time by watch	2 ^h 56' 56"
33° W. = (V. 133.)	2 12 00
Estim. time at Grenw. (57)	5 8 56
Sun's dec. Jan. 26th noon	18° 43' 24"
Decr. of decl. in 5 ^h 9' (V. 281)	3 13
Sun's decl. at ship	18 40 11 S.
Add	90 00 00
Polar distance	108 40 11
Co-lat. 38° 18' ar. co. log. sine	0,20776
Po. dist. 108 40 ar. co. log. sine	0,02347
D =	70 22
Co. alt. 80 16	
2) 150 38 (75° 19' log. sine	9,98558
2) 9 54 (4 57 log. sine	8,93594
	2) 19,15275
22 9	log. sine 9,57638
2	
44 18 =	2 ^h 57' 12" app. time.
2 56 56	watch time.
0 0 16	watch slow.

II. *May 24th, 1780, being in lat. 43° 16' N. long. 23° 30' E. at 7^h 16^m 30^s forenoon, the true alt. of the Sun's center was found to be 29° 4' : how was the watch?*

Time at the ship (May 23)	19 ^h 16' 30"
Long. 23° 30' E. (V. 133) =	1 34 00
Estim. time at Greenw.	17 42 30
Sun's dec. May 23d. noon	20° 45' 22" N.
Incr. of decl. in 17 ^h 42'	+ 8 8
Sun's decl. at ship	20 53 30 N.
Sun's polar distance	69 6 30
Co. alt. 60° 56'	
Co. lat. 46 44 ar. co. log. sine	0,13777
Po. dist. 69 6 ar. co. log. sine	0,02956
Sum	176 46
$\frac{1}{2}$ Sum 88 23	log. sine 9,99983
Co. alt. 60 56	
Diff. 27 27	log. sine 9,66368
	2) 19,83084
34 36 $\frac{1}{2}$ log. co. sine	9,91542
69 13 =	4 ^h 36' 52" before noon.
19 23 8	app. time.
19 16 30	time by watch.
6 38	watch too slow.

May

May 12th, 1780, at sea, in latitude $29^{\circ} 11' N.$ long. $95^{\circ} 5' W.$ the true altitude of the star Antares was found to be $14^{\circ} 53'$ at $9^h 1' 5''$ by a watch: What was the error of that watch?

Long. $95^{\circ} 5' W. = (V. 133.)$		6 ^h 20' 20"	Rt. ascen. Antares	16 ^h 15' 57"
			R. ascen. Sun at noon	3 19 29
Antares south nearly		12 56 28		12 56 28
Sum (long. being W.)		19 16 48	gives incr. rt. asc. subtr.	3 10
			Antares on the meridian at	12 53 18
Antares Zen. dist.	75° 7'		Ar. co. log. fin.	0,04609
Polar dist.	115 56		Ar. co. log. fin.	0,05895
Co. latit.	60 49			
Sum	251 52			
Half sum	125 56		log. fine	9,90832
Zenith. dist.	75 7			
Difference	50 49		log. fine	9,88937
				2)19,90273
	26 37		log. co. fine	9,95136
	2			
	53 14	$= (V. 133.)$	3 ^h 32' 56"	star short of meridian.
			12 53 18	star on the meridian.
			9 20 18	app. time.
			9 1 5	time by watch.
			19 17	watch too slow.

SECTION IX.

59. *To find the Latitude at Sea.*

Find the meridian altitude or zenith distance of the Sun or Star by Article 37, or 44, or 45, or 48, 49.

Apply the corrections for the dip of the horizon, the refraction in Art. 52, 53, 55, and semi-diameter, if the object be the sun.

Seek the Sun's or Star's declination in the tables at Art. 309, 312, Book V.; or in the Nautical Almanack, observing to correct the Sun's decl. for places more than 8° or 10° to the E. or W. of London, as at Art. 311, Book V.

In latitudes near the poles, when the Sun's declination exceeds the co-latitude, the Sun does not then set; and therefore two altitudes may be taken on the meridian; the least of which is called the altitude below the pole. The same may be understood of any other celestial object, which does not set.

Let the declination and the altitude, or zenith distance, be always named either north or south, according to the season of the year, and the situation of the object; and when it so happens that either of them is nothing, it may then be named either north or south at pleasure.

These remarks being premised, all the varieties of working a meridian observation for the latitude are contained in the solution of the following Problem:

PROBLEM I.

The declination of the Sun or a Star, and also its correct meridian altitude, or zenith distance being known; to find the latitude of the place of observation.

WHEN THE OBJECT RISES AND SETS.

60. CASE I. *If the zen. dist. and decl. have the same name.*

RULE. Their difference shews the latitude required.

Like the declination, when it is greater than the zenith distance; but unlike, when it is less.

61. CASE II. *If the zen. dist. and decl. have contrary names.*

RULE. Their sum shews the latitude required.

And is always like the declination.

When altitudes are given, take them from 90° for zenith distances.

62. WHEN THE OBJECT DOES NOT SET.

If the greatest meridian altitude or zenith distance can be taken, the preceding rules will serve; but when the least, or that below the pole, can only be taken: then

RULE. To the meridian altitude below the pole, add the co-declination, the sum shews the latitude, of the same name with the declination.

The demonstrations of these rules will be shewn in the Appendix.

EXAM. I. *The Sun's meridional zenith distance was observed to be $48^\circ 20'$ southerly, when he entered the sign Aries: Required the lat. of the place?*

The zenith distance	$48^\circ 20' \text{ S.}$
Declination	$00^\circ 00' \text{ S.}$
Lat. sought	$48^\circ 20' \text{ N. (60)}$

EXAM. II. *When the Sun entered the sign Libra, his meridian altitude was observed to be $53^\circ 32'$ in the north: What is the latitude of that place?*

The co-alt. or zen. dist.	$36^\circ 28' \text{ N.}$
Declination	$00^\circ 00' \text{ S.}$
Lat. sought	$36^\circ 28' \text{ S. (61)}$

EXAM.

EXAM. III. *At sea the Sun was observed in the zenith, when his declination was $22^{\circ} 10' N.$: What is the latitude of that place?*

The zenith distance	$00^{\circ} 00' N.$
Declination	$22^{\circ} 10' N.$
Lat. sought	$22^{\circ} 10' N. (60)$

EXAM. V. *The Sun was observed to be $47^{\circ} 25'$ distant from the zenith in the south, when his declination was $14^{\circ} 18' S.$: What is the lat. of the place of observation?*

The zenith distance	$47^{\circ} 25' S.$
Declination	$14^{\circ} 18' S.$
Lat. sought	$33^{\circ} 07' N. (60)$

EXAM. VII. *When the Sun's declination was $23^{\circ} 09' S.$ his meridian zenith distance was observed to be $8^{\circ} 25' S.$: Required the latitude of the place.*

The zenith distance	$8^{\circ} 25' S.$
Declination	$23^{\circ} 09' S.$
Lat. sought	$15^{\circ} 44' S. (60)$

EXAM. IX. *The Sun's meridian zenith distance was observed to be $32^{\circ} 57' S.$ when his declination was $10^{\circ} 38' N.$: What is the latitude of the place?*

The zenith distance	$32^{\circ} 57' S.$
Declination	$10^{\circ} 38' N.$
Lat. sought	$43^{\circ} 35' N. (61)$

EXAM. XI. *Observed the meridian altitude of the star Arcturus to be $61^{\circ} 14' S.$: Required the latitude.*

Mer. zen. dist.	$28^{\circ} 46' S.$
Arct. declin.	$20^{\circ} 26' N. (V. 312)$
Lat. sought	$49^{\circ} 12' N.$

EXAM. IV. *The Sun's merid. zenith distance was observed $21^{\circ} 08' S.$ when his decl. was the same: Required the latitude of the place of observation.*

The zenith distance	$21^{\circ} 08' S.$
Declination	$21^{\circ} 08' S.$
Lat. sought	$00^{\circ} 00' S. (60)$

EXAM. VI. *The Sun's meridian altitude was observed to be $54^{\circ} 27'$ north, when his declination was $19^{\circ} 57'$ north: Required the latitude of the place.*

The co-alt. or zen. dist.	$35^{\circ} 33' N.$
Declination	$19^{\circ} 57' N.$
Lat. sought	$15^{\circ} 36' S. (60)$

EXAM. VIII. *The Sun having $23^{\circ} 11' N.$ declination, his meridian altitude was found to be $79^{\circ} 23' N.$: What is the latitude of the place of observation?*

The co-alt. or zen. dist.	$10^{\circ} 37' N.$
Declination	$23^{\circ} 11' N.$
Lat. sought	$12^{\circ} 34' N. (60)$

EXAM. X. *Suppose the meridian altitude of the Sun was observed to be $48^{\circ} 14' N.$ when his decl. was $17^{\circ} 38' S.$: Required the latitude of the place.*

The co-alt. or zen. dist.	$41^{\circ} 46' N.$
Declination	$17^{\circ} 38' S.$
Lat. sought	$59^{\circ} 24' S. (61)$

EXAM. XII. *The altitude of the star Sirius, when on the meridian, was $24^{\circ} 32' S.$: Required the latitude.*

Mer. zen. dist.	$65^{\circ} 28' S.$
Sirius's declin.	$16^{\circ} 25' S. (V. 312)$
Lat. required	$49^{\circ} 03' N.$

63. Examples, wherein the foregoing Corrections are introduced.

I. By a fore observation, the altitude of the Sun's lower edge was found, by a Hadley's quadrant, to be $40^{\circ} 20' S.$ when the declination was $9^{\circ} 56' N.$ the eye being 20 feet above the horizon: Required the latitude of that place.

Apparent alt. $\odot$ lower edge	$40^{\circ} 20' S.$
Semidiameter. Add	$0 16$
Apparent altitude $\odot$ center	$40 36$
Dip. of the horiz. Subtract	$0 4$
App. alt. cor. by the dip.	$40 32$
Refraction. Subtract	$0 1$
True altitude $\odot$ center	$40 31$
True zenith distance	$49 29 S.$
Declination	$9 56 N.$
Latitude (61)	$59 25 N.$

II. By a back observation, with Hadley's quadrant, the apparent altitude of the Sun's lower edge was $25^{\circ} 12' S.$ when the declination was $21^{\circ} 14' S.$ and the eye 30 feet above the horizon: In what latitude was that observation made?

Apparent alt. $\odot$ lower edge	$25^{\circ} 12' S.$
Semidiameter. Subtract	$0 16$
Apparent altitude $\odot$ center	$24 56$
Dip of the horizon. Add	$0 5$
App. alt. cor. by the dip	$25 01$
Refraction. Subtract	$0 2$
True altitude $\odot$ center	$24 59$
True zenith distance	$65 1 S.$
Declination	$21 14 S.$
Latitude (60)	$43 47 N.$

III. Suppose an observer, whose eye is 35 feet above the water, should find the meridian altitude of Sirius to be $53^{\circ} 35' S.$ by the fore observation with a Hadley's quadrant: Required the latitude of the place of observation.

Apparent alt. of Sirius	$53^{\circ} 35' 0'' S.$
Dip. of the horiz. Subt.	$5 40$
Appar. alt. above hor.	$53 29 40$
Refraction. Subtract	$0 0 40$
True altitude of Sirius	$53 29 00$
True zenith distance	$36 31 00 S.$
Sirius's decl. (V. 312)	$16 25 08 S.$
Latitude (60)	$20 5 52 N.$

IV. In a ship where the eye of the observer is 25 feet above the horizon, suppose the meridian altitude of Arcturus should be found $61^{\circ} 21' S.$ by a back observation with Hadley's quadrant: What latitude was that ship in?

Appar. alt. of Arcturus	$61^{\circ} 21' 0'' S.$
Apparent zenith dist.	$28 39 0$
Dip of the horiz. Add	$4 46$
Zen. dist. clear of the dip	$28 43 46$
Refraction. Add	$0 0 30$
True zenith distance	$28 44 16 S.$
Arcturus's decl. (V. 312)	$20 29 15 N.$
Latitude (61)	$49 12 31 N.$

V. May 26, 1780, in longitude $67^{\circ} 30' E.$ of London, and the eye 18 feet high, the meridian altitude of the Sun's lower limb was $26^{\circ} 12' N.$ by a fore observation: Required the ship's latitude.

Ship's time $24^h 00' P. M.$ May 25.
 Lon. $67^{\circ} 30' E. = 4^h 30' E.$

Lond. time $19^h 30' P. M. 6^h 30' \times 3.$
 May 25, $\odot$ decl. $21^{\circ} 6' 19'' N.$ diff. $10' 18''$
 Incr. of decl. $8 12$ (V. 285)

At the ship $21 14 31 N.$ decl.

App. alt. $\odot$ lower limb $26^{\circ} 12'$

Semi-diameter $+ 16$

App. alt. $\odot$ center $26 28$

Dip. on 18 feet $- 4$

$26 24 00$

Refraction $- 1 55$

True alt. $\odot$ center $26 22 05$

Zenith dist. $63 37 55 N.$

Declination $21 14 31 N.$

Latitude $42 23 24 S.$

VI. June 12th, 1780, in a high northern latitude, $83^{\circ} W.$ of London, and the eye 20 feet high, the meridian altitude of the Sun's lower limb below the pole, was $8^{\circ} 15' N.$ by a fore observation: Required the latitude.

Ship's time $12^h 00' P. M.$
 Long. $83^{\circ} W. = 5^h 40' W.$

Lond. time $17 40 P. M. = 4^h 25' \times 4.$

June 12, $\odot$ decl. $23 13 17 N.$ diff. $3 16.$
 Incr. of decl. $2 28$

At the ship $23 15 45 N.$ declin.

App. alt. $\odot$ lower limb $8^{\circ} 15' N.$

Semidiameter $+ 16$

App. alt. $\odot$ center $8 31$

Dip. on 20 feet $- 4$

$8 27$

Refraction $- 6 18$

True alt. $\odot$ center $8 20 42 N.$

$\odot$ co-declination $66 44 15 N.$

Latitude $75 4 57 N.$

This method of finding the latitude from the meridian altitude of a celestial object is the most easy, when it can be put in practice: but as that is not always the case at sea, the Problems in Section VI. Book V. were introduced to supply the defect; from whence it has been judged proper to deduce some of the following most practical methods.

PREPARATION.

Take one, two, or more altitudes of the Sun in the forenoon, noting the time of each by a watch: if the meridian altitude cannot be obtained, take one, two, or more altitudes in the afternoon, noting also the times by the watch.

Let the morning altitudes, if there are three, be taken at equal intervals of time, if possible; if not, let the afternoon observations be taken at the same altitudes with the morning ones.

64. PROBLEM II.

When three zenith distances between the limits of 30 and 70° are taken within an hour of noon, at equal intervals of time between 15 and 30 minutes.

CASE I. If the first and third zenith distances are equal:

RULE. The middle one is the meridian zenith distance.

X

EXAM.

EXAMPLE. On a day when the Sun's declination was $18^{\circ} 34' N.$ some time near noon his zenith distance was found to be $32^{\circ} 29' S.$; and 22 minutes after, the zenith distance was $32^{\circ} 11'$: and 22 minutes afterwards the zenith distance was $32^{\circ} 29'$: Required the latitude of that place.

Here are equal zenith distances, at equal intervals of time from the middle observation; which therefore is a meridian observation.

Then $32^{\circ} 11' S. + 18^{\circ} 34' N. = 50^{\circ} 45' N.$ the latitude. (61)

(65) **CASE II.** If the two first, or two last, zenith distances are equal, that on the meridian falls between those equal ones.

RULE. From one of the equal zenith distances, take one eighth part of the difference between it and the greater zenith distance; and the remainder is that on the meridian.

EXAMPLE. Within an hour of noon, and at intervals of 22 minutes by a watch, the following zenith distances were observed, viz. 1st. $32^{\circ} 50\frac{1}{2}'$; 2d. $32^{\circ} 15\frac{1}{2}'$; 3d. $32^{\circ} 15\frac{1}{2}'$: Required the meridian zenith distance.

1st. $32^{\circ} 50,6'$ } diff. $35,1'$; its $\frac{1}{8} = 4,8'$; then $32^{\circ} 15,5 - 4,8 = 32^{\circ} 10,7'$.
2d. $32^{\circ} 15,5$ }

The meridian zenith distance is $32^{\circ} 11'$.

(66) **CASE III.** When the three zenith distances are all unequal:

If the two first are ascending, or two last descending, then noon falls in that interval whose two zenith distances are nearest to equality.

RULE. Let the difference between the greatest and middle be called A,
the difference between the first and last be called B.
the difference between B and four times A be called C.
the difference between B and C be called D.

Then C multiplied by itself, and the product divided by four times D, the quotient is a number of minutes, which subtract from the greatest zenith distance leaves the meridian zenith distance.

EXAM. I. In north latitude, the Sun was thrice observed near noon, when the zenith distance and times by a watch were as follow:

1st. At 11h. 27m. the zenith distance = $32^{\circ} 51'$,

2d. 11h. 51m. the zenith distance = $32^{\circ} 14'$,

3d. 12h. 15m. the zenith distance = $32^{\circ} 19'$.

Required the meridian zenith distance.

Zenith distance, 1st. $32^{\circ} 51'$ |
2d. $32^{\circ} 14'$ | A = 37 | $4A - B = 148 - 32 = 116 = C.$
3d. $32^{\circ} 19'$ | B = 32 | $C - B = 116 - 32 = 84 = D.$

And $\frac{116 \times 116}{84 \times 4} = 40'$, the correction.

Then $32^{\circ} 51' - 40' = 32^{\circ} 11'$, is the meridian zenith distance.

EXAM.

EXAM. II. In north latitude, three observations were made of the Sun near noon, at equal intervals of time, viz.

1st. At 11h. 2m. the zenith distance was $34^{\circ} 11'$
 11h. 20m. $35^{\circ} 9'$
 11h. 38m. $32^{\circ} 29'$

Required the meridian zenith distance.

Here $A=62$; $B=102$; $C=146$; $D=44$.

And $\frac{146 \times 146}{44 \times 4} = 121' = 2^{\circ} 1'$, the correction.

Then $34^{\circ} 11' - 2^{\circ} 1' = 32^{\circ} 10'$, is the meridian zenith distance.

EXAM. III. In the torrid zone, the Sun having $19^{\circ} 48' S.$ decl., three observations were taken at equal intervals of time, near noon, viz.

At 10h. 56m. the zen. dist. was $36^{\circ} 41' S.$ } Required the latitude.
 11 22 $34^{\circ} 26'$
 11 48 $33^{\circ} 16'$

Here $A=2^{\circ} 15' = 135'$; $B=3^{\circ} 25' = 205'$; $C=335$; $D=130$;

And $C^2 = 112225$; $4D = 520$. Then $\frac{112225}{520} = 216' = 3^{\circ} 36'$.

And $36^{\circ} 41' - 3^{\circ} 36' = 33^{\circ} 05'$, the meridian zenith distance.

Then $33^{\circ} 05' - 19^{\circ} 48' = 13^{\circ} 17' N.$ the latitude sought. (60.)

EXAM. IV. In a low north latitude, the Sun having $14^{\circ} 24' S.$ declination; when the watch shewed 11h. 42m., 12h. 20m., and 12h. 58m., the Sun's zenith distances were $43^{\circ} 19'$, $43^{\circ} 23'$, and $45^{\circ} 19'$, respectively: Required the latitude.

11h. 42m. zen. dist.	$43^{\circ} 19'$	} $B = 2^{\circ} 0' = 120.$ $A = 1^{\circ} 56' = 116.$ $C = 344.$ $D = 224.$	} $4A = 464.$ $4D = 896.$
12 20	$43^{\circ} 23'$		
12 58	$45^{\circ} 19'$		
2L, C	344	5,07312	Greatest zenith distance $45^{\circ} 19'$
L, 4D subtr.	896	2,95231	Take the correction $2^{\circ} 12'$
L, correction	132	2,12081	Meridian zenith distance $48^{\circ} 7' S.$
			Declination $14^{\circ} 24' S.$
			Latitude (60) $28^{\circ} 43' N.$

67.

PROBLEM III.

When three zenith distances, between the limits of 30° and 70° are taken within an hour and a half of noon, at unequal intervals of time.

RULE 1st. Let the difference in minutes between the greatest and middle zenith distances be called A ; and the interval of time called a : the difference between the first and last zenith distances be called B : and the corresponding interval of time called b .

2d. Let the difference between the products of A by b and B by a be taken.

From the logarithm of this difference take the logarithm of b , there remains a logarithm, which call N .

3d. Add

3d. Add together the logarithm of N.

twice the log. of the diff. between a and $\frac{1}{2}b$.

Ar co. log. of the diff. between a and b .

Ar co. logarithm of a .

Their sum gives a logarithm, which call M.

4th. Seek the numbers to N, M, $\frac{1}{2}B$; their sum gives E.

From four times E take B, remains c; and B taken from c, leaves D.

And the logarithm of four times D taken from twice the logarithm of c, gives the logarithm of the correction in minutes.

5th. Then the greatest zenith distance lessened by the correction, gives the meridian zenith distance.

EXAM. I. Three observations being made of the Sun, at a place in north latitude, viz. at 10h. 40m. the zenith distance was $35^{\circ} 53'$,

11 9 was 33 $44\frac{1}{2}$,

11 51 was 32 14,

How much was the Sun's meridian zenith distance?

10h. 40m. }	zen. dist. $35^{\circ} 53'$ }		
11 9 }	$a=29m.$ 33 $44,5$ }	$A=128,5'$	$a \cos \frac{1}{2}b=6,5$
11 51 }	$b=71$ 32 14 }	$B=219$	$a \cos b=42.$
$128,5 \times 71 = (A \times b) = 9123,5$			
$219 \times 29 = (B \times a) = 6351$			
the diff. = 2772,5			
Logarithm diff. = 2772,5	3,44287	$\frac{1}{2}B = 109,5$	
Logarithm $b=71$	1,85126	$N = 39,5$	
Logarithm $N=39,5$	1,59161	$M = 1,3$	
Twice log. $a \cos \frac{1}{2}b = 6,5$	1,62583	$E = 150,3$ and $4E=601,2$	
Ar. co. log. $a \cos b = 42$	8,37675	$B = 219$	
Ar. co. log. $a = 29$	8,53760	$C = 382,2$	
Logarithm $M=1,3$	0,13179	$D = 163,2$ and $4D=652,8$	
Twice log. $c=382,2$	5,16458	Greatest zenith distance	$35^{\circ} 53'$
Logarithm $4D=652,8$	2,81478	Correction	$223 = 3 43$
Log. correction = 223	2,34980	Merid. zenith distance	$32 10'$

EXAM. II. To the northward of the tropic of Cancer, when the Sun's declination was $14^{\circ} 24'S.$; at the times 11h. 42m., 12h. 26m., 12h. 58m., shewn by a watch, the Sun's zenith distances were $43^{\circ} 19'$, $43^{\circ} 33'$, $45^{\circ} 19'$, respectively: Required the latitude.

11h. 42m. }	1st. zen. dist. $43^{\circ} 12'$ }		
12 26 }	$b=76m.$ 43 33 }	$B=120$	$a \cos \frac{1}{2}b=6$
12 58 }	$a=32$ 45 19 }	$A=106$	$a \cos b=44.$
$A \times b = 106 \times 76 = 8056$; $B \times a = 120 \times 32 = 3840$; diff. of prod. 4216.			
L	4216	3,62490	$\frac{1}{2}B = 60$
L, b	76	1,88081	$N = 55,5$
L, N	55,5	1,74409	$M = 1,4$
$2L, a \cos \frac{1}{2}b$	6	1,55630	$E = 116,9$ and $4E=467,6$
$2L, a \cos b$	44	8,35655	$B = 120$
L, a	32	8,49485	$C = 347,6$
L, M	1,4	0,15179	$D = 227,6$, and $4D=910,4$
$2L, C$	347,6	5,08216	Greatest zenith distance
L, 4D	910,4	2,95923	Correction
L, correction	132,7	2,12293	Merid. zenith distance
			Declination
			Latitude

PROBLEM IV.

68.

When three altitudes are taken at equal intervals of time, at any distance from noon: See Book V. Article 202.

RULE 1st. Seek the natural sines of the three given altitudes. (V. 185)

Call the difference between the first and third altitudes, D; between the second and third, F.

Put E for the sum of D and twice F, when the degrees in the third altitude fall between those of the first and second; otherwise put E for the difference between D and twice F.

2^d. Add together the log. co-tang. of half one interval of time (in deg.) the log. of E, and the ar. co-log. of D (each in numbers)

Their sum is the logarithmic tangent of an angle A; or of its supplement, if the first altitude exceeds the third: convert the angle A into time. (V. 133)

To A add one interval; then the difference between this sum and six hours will shew the time from noon, when the last observation was made.

Hence, by the intervals, the other times are known relative to the noon of the place of observation.

3^d. Add together the ar. co. log, co-sine of A.

the ar. co. log. sine of one interval observed,

and the log. of D, their sum is the log. of a number B.

4th. To the logarithm of B add twice the logarithmic sine of half the least time from noon; seek the number, and add it to the natural sine of the greatest altitude, the sum is the natural sine of the meridian altitude.

5th. The number B lessened by the natural sine of the meridian altitude, gives the natural sine of the midnight depression.

Then the half sum, and the half difference, being taken, of the degrees and minutes answering to the sines of the meridian altitude and midnight depression, give the co-latitude and declination. (V. 185)

If the zenith falls between the equator and the Sun, the half sum is the co-declination, and the half difference is the latitude.

EXAM. I. Between the tropics, the Sun's altitude was observed some time in the forenoon, to be $73^{\circ} 22'$; after waiting 26 minutes, its altitude was $78^{\circ} 50'$, and 26 minutes after, its altitude was $82^{\circ} 55'$: Required the latitude of that place.

$73^{\circ} 22'$, nat. sine	,95816	(See Book V. note to art. 185.)	
$78^{\circ} 50'$	,98107	,03421 = D	and ,01161 = E;
$82^{\circ} 55'$	,99237	,01130 = F	also 26 m. = $6^{\circ} 30'$
		,02260 = 2F	its half = 3 15
L, $3^{\circ} 15'$	11,24577	L, A $80^{\circ} 30'$	0,78239
L, E = 0,01161	8,06483	L, $6^{\circ} 30'$	0,94614
L, D = 0,03421	1,46584	L, D $0,03421$	8,53416
		L, B $1,8310$	10,26269
L, A = $80^{\circ} 30'$	10,77644	2L, $1^{\circ} 30'$ ($= \frac{12 \text{ m.}}{2}$)	6,83584
		0,001255	7,09853
		,99237	
Or A = 5 hours 22 minutes.		Mer. alt. 0,99362 = nat. sine $83^{\circ} 32'$.	
Now 5 h. 22 m. + 26 m. = 5 h. 48 m.		Mid. dep. 0,8374 = nat. sine $56^{\circ} 52'$	
Then 6 h. — 5 h. 48 m. = 0 h. 12 m.		half sum = $70^{\circ} 12'$ the co-declinat.	
So the greater alt was at 11 h. 48 m.		half diff. = 13 20 the latitude.	
the middle at 11 22			
the least at 10 56			

EXAM.

EXAM. II. In the north temperate zone, the Sun having south declination, his altitude was observed to be $8^{\circ} 37\frac{1}{2}'$; and 66 minutes afterwards, his altitude was $13^{\circ} 51\frac{1}{2}'$; and 66 minutes after that, his altitude was $16^{\circ} 34'$: Required the latitude.

At some time, alt. $8^{\circ} 37\frac{1}{2}'$ nat. line ,14997
 66 m. 13 $51\frac{1}{2}$,23955 } ,13517 = D.
 66 m. 16 34 ,28514 } ,04559 = F.
 2F = ,09118 & E = ,04398.

66 m. = $16^{\circ} 30'$. And 6 h. — 1 h. 6 m. = 4 h. 54 m.

L, s'	$8^{\circ} 15'$	10,83865	L, s', A	$65^{\circ} 59'$	0,39040
L, E	= 0,04398	8,64325	L, s',	16 30	0,54666
L, D	= 0,13517	0,86913	L, D	0,13517	9,13087
			L, B	1,1693	10,06793
L, s, A	= $65^{\circ} 59'$	10,35103	2L, s,	$3^{\circ} 45\frac{1}{2}'$	7,63312

Or A = 4 h. 23 m. 56 f.

Now 4 h. 23 m. 56 f. + 1 h. 6 m. = 5. 29. 56.

And 6 h. — 5 h. 29 m. 56 f. = 0 h. 30 m. 4 f.

11 29 56 at last alt.

10 23 56 mid. alt.

9 17 56 least alt.

Greater alt.

s, merid. alt.

s, dep.

the $\frac{1}{2}$ sum = $39^{\circ} 12\frac{1}{2}'$ the co-latitude

the $\frac{1}{2}$ diff. = 22 $20\frac{1}{2}'$ the declination.

EXAM. III. In a high north latitude, and the Sun to the eastward of the meridian, his altitude was observed to be $41^{\circ} 53'$; and 2 h. 16 m. after, his altitude was $50^{\circ} 23\frac{1}{2}'$; and 2 h. 16 m. after that, his altitude, was again observed to be $44^{\circ} 54'$: Required the latitude.

In the forenoon, alt. $41^{\circ} 53'$ fine ,66762
 1st interval 2 h. 16 m. = $34^{\circ} 0'$ $50^{\circ} 23\frac{1}{2}'$,77042 } D = ,03825
 2d interval 2 h. 16 m. 44 54 ,70587 } F = ,06455
 2F = ,12510

Here as the 3d. altit. falls between 1st. and 2d; D + 2F = E = ,16735

Now L, s',	$17^{\circ} 0'$	10,51466	L, s', A	$86^{\circ} 0'$	1,15642
L, E	0,16735	9,22362	L, s',	34 0	6,25244
L, D	0,03825	1,41737	L, D	0,03825	8,58263
			L, B	0,98060	9,99149

L, s, A $86^{\circ} 0'$ 11,15565

And 86° = 5 h. 44 m.

5 h. 44 m. + 2 h. 16 m. = 8 h. 0 m.

8 h. — 6 h. = 2 h. à noon at 3d. alt.

1st. altitude at 9 h. 28 m.

2d. altitude at 11 44

3d. altitude at 2 0

2L, s, 15° ($= \frac{2h.}{2}$) 8,82599

0,06569 8,81748

,70587, fine 3d altitude.

$50^{\circ} 30'$,77156, fine merid. altitude.

,98060, number B.

12 4 ,20904, fine of mid. deprec.

Hence the latitude is $58^{\circ} 43'$ N.; and declination $19^{\circ} 13'$ N.

EXAM.

EXAM. IV. In a low northern latitude, and the Sun having south declination, his altitude was observed in the forenoon to be $61^{\circ} 47'$; and 2 h. 30 m. after, his altitude was $64^{\circ} 29\frac{1}{2}'$, and 2 h. 30 m. after, his altitude was $36^{\circ} 5\frac{1}{4}'$: Required the latitude.

Forenoon	alt. $61^{\circ} 47'$ fine	,88117	} } D = ,29215 F = ,31347 2F = ,62694
1st interval 2 h. 30 m. = $37^{\circ} 30'$	64 $29\frac{1}{2}'$	,90249	
2d interval 2 h. 30 m.	36 $5\frac{1}{4}'$	,58902	

Now $L, A = 18^{\circ} 45'$	10,46922	$L, S, 73^{\circ} 30'$	0,54666
$L, E = 0,33579$	9,52477	$L, S, 37^{\circ} 30'$	0,21555
$L, D = 0,29215$	0,53439	$L, D 0,29215$	9,46561
$L, A 106^{\circ} 30'$	10,52838	$L, B 1,6897$	10,22782
And $A = 7$ h. 6 m.		$2L, S, 27^{\circ}$	9,31409
7 h. 6 m. + 2 h. 30 m. = 9 h. 36 m.		0,34826	9,54191
And 9 h. 36 m. — 6 h. = 3 h. 36 m.		58902	
the 3d. alt. at 3 h. 36 m. P. M.		$69^{\circ} 36'$,93728, fine merid. altitude.	
2d. 1 6 P. M.		B 1,6897	
1st. 10 36 A. M.		$48^{\circ} 48'$,7524, fine mid. depression.	
		Hence latitude $30^{\circ} 48'$ N.	
		Declination $10^{\circ} 24'$ N.	

69.

PROBLEM V.

When three altitudes are taken at unequal intervals of time †.

RULE 1st. Let the interval between the 1st and 3d times be called M ,
between the 1st and 2d m ,
between the 2d and 3d n ,

and let the times M, m, n , be converted into degrees. (V. 133)

Seek the natural sines of the three observed altitudes. (IV. 256)

And let the difference between the 1st and 3d be called D ,
between the 2d and 3d F .

2d. Add together the log. sines of $\frac{1}{2} m$ and $\frac{1}{2} n$, gives the log. of $\frac{1}{2} A$.

3d. To the log. co-sine of $\frac{1}{2} m$ add the log. sine of $\frac{1}{2} n$, the sum is the log. of $\frac{1}{2} B$.

4th. Add together the ar. co. log. of D , the log. of F , and the log. sine of $\frac{1}{2} M$, the sum is log. of $\frac{1}{2} C$.

Take the difference between the numbers $\frac{1}{2} B$ and $\frac{1}{2} C$, call it $\frac{1}{2} E$.
Or let $\frac{1}{2} E$ be the sum of $\frac{1}{2} B$ and $\frac{1}{2} C$, when the degrees in the 3d altitude fall between those of the 1st and 2d altitudes.

5th. From the logarithm of $\frac{1}{2} E$ take the logarithm of $\frac{1}{2} A$, the remainder (10 being added to the index) is the logarithmic tangent of an arc G ; or of its supplement, when the first altitude exceeds the second.

* See Book IV. 256.

† See Book V. Article 200.

Take

Take the difference between G and the complement of $\frac{1}{2} M$, the remainder is an arc H , shewing the time from noon when the last altitude was taken. Hence the other times are known.

6th. Add together the ar. co. log. co-fine of G ,
the ar. co. log. fine of $\frac{1}{2} M$,
and, the log of D , their sum is the log. of a number I .

7th. To log. of I add twice the log. fine of $\frac{1}{2} H$, the sum is the log. of K .

8th. The number K added to the natural fine of the third altitude gives the natural fine of the meridian altitude.

And the number I lessened by the natural fine of the meridian altitude, gives the natural fine of the midnight depression.

The half sum and half difference of the degrees shewing the meridian altitude and midnight depression, will give the co-latitude and declination; or co-declination and latitude, when the zenith falls between the Sun and the equator. (V. 185.)

EXAM. I. In north latitude, the Sun having south declination; at 8 h. 40 m. 10 h. 00 m. and 11 h. 48 m. by a watch, the altitudes of the Sun were $30^{\circ} 41\frac{1}{4}'$, $45^{\circ} 37\frac{1}{2}'$ and $56^{\circ} 44'$, respectively: Required the latitude.

$$\begin{array}{l} M = 3 \text{ h. } 8 \text{ m.} = 47^{\circ} \\ m = 1 \quad 20 \quad = 20 \\ n = 1 \quad 48 \quad = 27 \end{array} \left| \begin{array}{l} 1^{\text{st}} \text{ alt.} = 30^{\circ} 41\frac{1}{4}' \text{ nat. fine } 0,51037 \\ 2^{\text{d}} \quad \quad = 45 \quad 27\frac{1}{2} \quad \quad \quad 0,71474 \\ 3^{\text{d}} \quad \quad = 56 \quad 44 \quad \quad \quad 0,83615 \end{array} \right. \left. \begin{array}{l} \\ \\ \end{array} \right\} \begin{array}{l} D = 0,32578 \\ F = 0,12141 \end{array}$$

$L, \frac{1}{2} M$	$10^{\circ} 0'$	9,23967	Here $\frac{1}{2} B - \frac{1}{2} C = \frac{1}{2} E$.
$L, \frac{1}{2} n$	$13 \quad 30$	9,36818	And $\log \frac{1}{2} E - \log \frac{1}{2} A = L, \frac{1}{2} G$.
$L, \frac{1}{2} A$	0,04054	8,60785	Also $12 \text{ h.} - 12 \text{ m.} = 11 \text{ h. } 48 \text{ m.}$ the
			time of the last altitude.
$L, \frac{1}{2} m$	$10^{\circ} 0'$	9,99335	So the watch shewed true time.
$L, \frac{1}{2} n$	$13 \quad 30$	9,36818	$E, \frac{1}{2} G$ $63^{\circ} 30'$ 0,35047
			$L, \frac{1}{2} M$ $23 \quad 30$ 0,39930
$L, \frac{1}{2} B$	0,22990	9,36153	L, D 0,32578 9,51293
L, D	0,32578	0,48707	L, I 1,83110 10,26270
L, F	0,12141	9,08425	$2L, \frac{1}{2} H$ $1^{\circ} 30'$ 6,83584
$L, \frac{1}{2} M$	$23^{\circ} 30'$	9,60070	L, K 0,00125 7,09854
			0,83615 = fine 3d. alt.
$L, \frac{1}{2} C$	0,14860	9,17202	$56^{\circ} 52'$ 0,8374 = fine mer. alt.
$L, \frac{1}{2} E$	0,08130	8,91009	$83^{\circ} 34'$ 0,99370 = fine mid. dep.
$L, \frac{1}{2} \angle G$	$63^{\circ} 30'$	10,30224	Hence latit. = $13^{\circ} 21' \text{ N.}$
			Declination = $19 \quad 47 \text{ S.}$
	66 30 = compl. of $\frac{1}{2} M$.		
$H =$	3 0 = 0 h. 12 m. à noon.		

EXAM. II. The Sun's altitude was $16^{\circ} 34'$; and 50 minutes after, the altitude was $14^{\circ} 16'$; and 82 minutes after the altitude was $8^{\circ} 37\frac{1}{2}'$: Required the latitude.

M=2h. 12m. = 33° 0'	1ft. alt. = 16° 34'	nat. fin. 0,28514	} D=0,13517 } F=0,10489
m=0 50 = 12 30	2d. = 14 16	0,25486	
n=1 22 = 20 30	3d. = 8 37½	0,14997	
L _{1/2} ^{1/2} M 6° 15'	9,03690	Here ½C - ½B = ½E.	
L _{1/2} ^{1/2} N 10 15	9,25028	And Lt, of supplement of c.	
L _{1/2} A 0,01937	8,28718	Also 2h. 42m. is time at 3d. altitude,	
L _{1/2} ^{1/2} M 6° 15'	9,99741	I 20	at 2d. altitude,
L _{1/2} ^{1/2} N 10 15	9,25028	12 30	at 3d. altitude.
L _{1/2} B 0,17689	9,24769	L _{1/2} ^{1/2} G 114° 0'	0,39069
L _{1/2} D 0,13517	0,86911	L _{1/2} ^{1/2} M 16 30	0,54666
L _{1/2} F 0,10489	9,02073	L, D 0,13517	9,13089
L _{1/2} ^{1/2} M 16° 30'	9,45334	L, I 1,17007	10,06824
L _{1/2} ^{1/2} C 0,22038	9,34318	2L _{1/2} ^{1/2} H 20° 15'	9,07845
L _{1/2} ^{1/2} E 0,04349	8,63839	L, K 0,14017	9,14669
L _{1/2} ∠G 114° 0'	10,35121	0,14997=fine of 3d. alt.	
73 30=compl. of ½ M.		16° 52' ,29014=fine merid. alt.	
H=40 30=2h. 42m. à noon.		61 38 ,87993=fine mid. depr.	
		Hence lat.=50° 45' N. Decl. 22° 23' S.	

EXAM. III. Some time in May, and in a high northern latitude, three successive altitudes of the Sun were, 41° 53', 50° 7½', 44° 54½'; the intervals of time being 2 h. 2 m. and 2 h. 30 m.: Required the latitude.

M=4h. 32m. = 68° 0'	1st. alt. = 41° 53'	nat. fin. 0,66762	} D=0,03827 } F=0,06154
m=2 2 = 30 30	2d. = 50 7½	0,76743	
n=2 30 = 37 30	3d. = 44 54½	0,70589	
L _{1/2} ^{1/2} m 15° 15'	9,42001	Here ½C + ½B = ½E.	
L _{1/2} ^{1/2} n 18 45	9,50710	Also 2h. 0m. = time at 3d. altitude	
L _{1/2} A 0,08455	8,92711	11 30	= time at 2d. altitude
		9 28	= time at 1st. altitude
L _{1/2} ^{1/2} m 15° 15'	9,98443	L _{1/2} ^{1/2} G 86° 0'	1,15642
L _{1/2} ^{1/2} n 18 45	9,50710	L _{1/2} ^{1/2} M 34 0	0,25244
		L _{1/2} D 0,03827	8,58286
L _{1/2} B 0,31012	9,49153	L _{1/2} I 0,98112	9,99172
L _{1/2} D 0,03827	1,41714	2L _{1/2} ^{1/2} H 15° 0'	8,82599
L _{1/2} F 0,06154	8,78916	L _{1/2} K 0,06572	8,81771
L _{1/2} ^{1/2} M 34° 0'	9,74756	0,70589 = fine of 3d. alt.	
L _{1/2} ^{1/2} C 0,89921	9,95386	50° 30' 0,77161 = fine merid. alt.	
L _{1/2} ^{1/2} E 1,20933	10,08254	12 6 0,20951 = fine mid-n. depr.	
L _{1/2} ∠G 86° 0'	11,15543	Hence lat. = 58° 42' N.	
56 0 = compl. of ½ M.		Declinat. = 19 12 N.	
H=30 0 = 2h. from noon.			

EXAM. IV. Suppose three successive altitudes of the Sun were, $61^{\circ} 47'$, $66^{\circ} 39\frac{1}{2}'$, $36^{\circ} 5\frac{1}{4}'$, taken at intervals of 2h. 14m. and 2h. 46m. Required the time of the day, and the latitude.

$M = 5h. 0m. = 75^{\circ} 0'$		$\left. \begin{array}{l} 1st. alt. = 61^{\circ} 47' \text{ nat. sin. } 0,88117 \\ 2d. = 66^{\circ} 39\frac{1}{2}' \\ 3d. = 36^{\circ} 5\frac{1}{4}' \end{array} \right\} \begin{array}{l} 0,91726 \\ 0,58902 \end{array} \right\} \begin{array}{l} D = 0,29215 \\ F = 0,32824 \end{array}$		
$m = 2$	$14 = 33^{\circ} 30'$			
$n = 2$	$46 = 41^{\circ} 30'$			
$Ls, \frac{1}{2}m$	$16^{\circ} 45'$	9,45969	Here $\frac{1}{2}G - \frac{1}{2}B = \frac{1}{2}E$.	
$Ls, \frac{1}{2}n$	$20^{\circ} 45'$	9,54936	And G is a supplement.	
			Also 3h. 36m. = time at 3d. alt.	
$L, \frac{1}{2}A$	0,10211	9,00905	12 50	= time at 2d. alt.
			10 36	= time at 1st. alt.
$Ls, \frac{1}{2}m$	$16^{\circ} 45'$	9,98117	Ls, G	$106^{\circ} 30'$ 0,54666
$Ls, \frac{1}{2}n$	$20^{\circ} 45'$	9,54936	$Ls, \frac{1}{2}M$	$37^{\circ} 30'$ 0,21535
			L, D	0,29215 9,46561
$L, \frac{1}{2}B$	0,33926	9,53053		
			L, I	1,68969 10,22782
L, D	0,29215	0,53439	$2Ls, \frac{1}{2}H$	$27^{\circ} 0'$ 9,31409
L, F	0,32824	9,51619		
$L, \frac{1}{2}M$	$37^{\circ} 30'$	9,78445	L, K	0,34825 9,54191
$L, \frac{1}{2}C$	0,68396	9,83503	0,58902 = sine of the 3d alt.	
$L, \frac{1}{2}E$	0,34470	9,53744	$69^{\circ} 36'$ 0,93727 = sine merid. alt.	
$L, \angle G$	$106^{\circ} 30'$	10,52839	$48^{\circ} 48'$ 0,75242 = sine mid. depr.	
$52 30 = \text{compl. of } \frac{1}{2}M.$		Hence latitude = $30^{\circ} 48' N$.		
		Declination = $10^{\circ} 24' N$.		
$n = 54$		0 = 3h. 36m. à noon.		

70.

PROBLEM VI.

Given two altitudes of the Sun, the interval of time between the two observations, the Sun's declination, and the latitude by dead reckoning; to find the true latitude.

SOLUTION.

1st. Convert the interval of time into degrees, and take its half. Also take the half sum and half difference of the two altitudes.

First Operation.

2d. Add together the five following logarithms.
log. co-f. of the half sum of the two latitudes.
log. sine of the half diff. of the two altitudes.

Ar. co. log. sine of the half interval.

Ar. co. log. co-f. of the declination.

Ar. co. log. co-f. of the lat. by account; their sum * is the log. sine of an arc.

3d. Take the diff. between this arc and the half interval; and the half of this diff. is half the time from noon, when the greater altitude was taken, or half their sum is the time from noon, when the less altitude was taken.

4th. Add together the three following logarithms.

log. co-sine of the declination.

log. co-sine of the latitude by account.

Twice log. sine of half the time from noon, in degrees.

* Rejecting the tens in the sum of the indices in this and the following logarithmic work.

Seek the number to the logarithm of the sum, then that number doubled is a number, called the correction; which being added to the natural sine of that observed altitude, half the time of which from noon was taken, gives the natural sine of the mer. alt. which is by it known: and hence the lat. is known by Problem I.

71.

REMARKS.

But to know if the latitude thus found is accurate, make a *second operation*. Thus,

To the sum of the first four logs. used in the 2d article of the rule, add the ar. co. log. co-sine of the latitude found by article 4th. The sum is the log. sine of an arc.

Work by the 3d and 4th articles, for a corrected latitude; and if it comes out the same, within a minute or two, as that found by the first operation, it may be esteemed the true latitude.

Or, if the difference between the results of the two operations do not exceed about $\frac{1}{4}$ th of the difference between the latitude assumed, and that first found, the last result may be accounted sufficiently correct.

But if the difference between the results of both operations is much greater than the said $\frac{1}{4}$ th part, then a third operation with the last found latitude will generally give the latitude exact enough.

When the latitudes found by the first and second operations have one greater and one less than the latitude by account; or if these latitudes found differ by a degree or more; then make a third operation with the half sum, or mean, of these two latitudes; and if the latitude found differs from the said mean, half their sum will generally give the latitude very near the truth.

When both observations are made in the forenoon, or both in the afternoon;

The half interval is half the difference of the times from noon:

And the first found arc is half the sum of the times from noon.

But when the observations are, one before, and the other after, noon;

The $\frac{1}{2}$ interval is the $\frac{1}{2}$ sum; and the first found arc is the $\frac{1}{2}$ diff. of the times from noon.

The $\frac{1}{2}$ diff. added to the $\frac{1}{2}$ sum gives the time of the observation farthest from noon.

And the $\frac{1}{2}$ diff. taken from the $\frac{1}{2}$ sum gives the time of the observ. nearest to noon.

72. The times of observation should be taken to seconds, or at least to quarters, or thirds of a minute of time. They are best when taken between the times of 9h. A. M. and 3h. P. M.: the interval of time between the observations ought not to exceed five hours, nor be much less than the time from noon at the taking of the greatest altitude: in general the interval should not be much less than about $\frac{1}{4}$ of an hour.

73. This problem is best suited to situations, where the Sun's meridian zenith distance is not much less than half the latitude: for in latitudes where the Sun approaches near to the zenith, the observations are to be taken much nearer to noon; and the rule instead of approximating, will in some cases give the results of successive operations wider and wider from the truth; in such cases it is best to apply Prob. II.

74. About the year 1740, Mr. *John Douwes*, a mathematician at Amsterdam, and examiner of the marine cadets there, first communicated to the sea officers of Holland a solution of this problem, by the help of a set of solar tables which he had computed for that purpose. Manuscript copies coming into the hands of several English officers, who held the method in high esteem, it was in the autumn of the year 1759 published, without any demonstration; but one has since been given by several persons. In particular Dr. Pemberton communicated to the Royal Society the whole composition, and shewed the limits, or where the method diverges, together with other useful particulars. This curious paper of the Doctor's was published in the Philosophical Transactions for the year 1760.

Mr. Douwes's tables consist of four columns; in the first column stands the time to every half minute, extended to six hours: the second column, called half the lapsed time, contains the arithmetical complement of the logarithmic sines of the degrees corresponding to the times they stand against, in the first column: the third column, called middle times, are the logarithms of twice the natural sines of the times, in degrees, which they stand against: and in the fourth column are the logarithmic versed sines of the times, in degrees, they stand against. But the preceding solution requires no other tables than such as are in the common books of navigation*.

EXAM. I. At 9h. 18m. and at 11h. 30m. by a watch, the Sun's altitudes were respectively $8^{\circ} 37\frac{1}{2}'$, and $16^{\circ} 34'$; the Sun's declination was $22^{\circ} 23'S.$; and the latitude by account $50^{\circ} 40'N.$: Required the true latitude.

9h. 18m. } 11 30 }	2h. 12m. = 33° ; altitudes {	$8^{\circ} 37\frac{1}{2}'$ 16 34 nat. sine 0,28514.
$\frac{1}{2}$ interval or $\frac{1}{2}$ diff. times }	= $16^{\circ} 30'$	2) $25 \ 11\frac{1}{2}$ $12^{\circ} 35\frac{3}{4}' = \frac{1}{2}$ sum alts.
$Ls, \frac{1}{2}$ sum alts. = $12^{\circ} 35\frac{3}{4}'$	9,98942	$Ls, \frac{1}{2}$ diff. times = 16 30
$Ls, \frac{1}{2}$ diff. alts. = $3 \ 58\frac{1}{4}$	8,84041	$Ls, \frac{1}{2}$ declinat. = $22 \ 23$
$Ls, \frac{1}{2}$ diff. times = 16 30	0,54666	$Ls, \frac{1}{2}$ latitude = $50 \ 40$
$Ls, \frac{1}{2}$ declinat. = $22 \ 23$	0,03402	
$Ls, \frac{1}{2}$ latitude = $50 \ 40$	0,19803	
$L, \text{ an arc} = 23 \ 57\frac{1}{2}$	9,60854	
	16 30	
	7 $27\frac{1}{2}$	
Its half = $3 \ 43\frac{3}{4}$	t. from noon.	
		$Ls, \text{ declinat.} = 22^{\circ} 23'$ 9,96598
		$Ls, \text{ latitude} = 50 \ 40$ 9,80197
		$2Ls, \frac{1}{2} \text{ time} = 3 \ 43\frac{3}{4}$ { 8,82317
		$L, \frac{1}{2} \text{ correct.} = 0,00247$ 7,39429
		Correction = 0,00494 to be added.
		nat. s. of $16^{\circ} 34'$.28514 great alt.
		s, merid. alt. = 29008 $16^{\circ} 52'$
		Meridional zenith distance 73 8 S.
		Declination 22 23 S.
		True latitude 50 45 N.

* Among the several publications of these solar tables, the most extensive and useful is in the Nautical Almanac for the year 1771.

EXAM. II. At 12 h. 12 m. and at 3 h. 20 m. by a watch, the Sun's altitudes were $56^{\circ} 44\frac{1}{8}'$, and $30^{\circ} 41\frac{1}{4}'$ respectively; the Sun's declination was $19^{\circ} 48'$ S. and the latitude, by dead reckoning, $13^{\circ} 14'$ N.: Required the true latitude.

$$\left. \begin{array}{l} 12^{\text{h}} 12^{\text{m}} \\ 3 \quad 20 \end{array} \right\} 3 \text{ h. } 8 \text{ m.} = 47^{\circ}; \text{ altitudes } \left\{ \begin{array}{l} 56^{\circ} 44\frac{1}{8}' \\ 30^{\circ} 41\frac{1}{4}' \end{array} \right. \text{ nat. sine } 0,83615.$$

$$\begin{array}{r} \text{half diff. times} = 23^{\circ} 30' \\ \begin{array}{r} 87 \quad 25\frac{3}{8} \\ 26 \quad 3 \end{array} \left| \begin{array}{r} 43 \quad 43 \\ 13 \quad 1\frac{1}{2} \end{array} \right. \begin{array}{l} = \frac{1}{2} \text{ sum altitudes.} \\ = \frac{1}{2} \text{ diff. altitudes.} \end{array} \end{array}$$

$Ls, \frac{1}{2} \text{ sum alts.} = 43^{\circ} 43'$	$9,85900$	$Ls, \text{ declinat.} = 19^{\circ} 48'$	$9,97353$
$Ls, \frac{1}{2} \text{ diff. alts.} = 13 \quad 1\frac{1}{2}$	$9,35290$	$Ls, \text{ latitude} = 13 \quad 14$	$9,98831$
$Ls, \frac{1}{2} \text{ diff. times} = 23 \quad 30$	$0,39930$	$2Ls, \frac{1}{2} \text{ time} = 1 \quad 29\frac{3}{4}$	$\left. \begin{array}{l} 8,41630 \\ 8,41630 \end{array} \right\}$
$Ls, \text{ declination} = 19 \quad 48$	$0,02647$	$L, \frac{1}{2} \text{ correct.} = ,000623$	$6,79444$
$Ls, \text{ latitude} = 13 \quad 14$	$0,01169$	$\text{Correction} = ,00125 \text{ to be added,}$	
$Ls, \text{ an arc} = 26 \quad 29\frac{1}{2}$	$9,64936$	$s, \text{ great alt.} = ,83615$	
$23 \quad 30$		$s, \text{ merid. alt.} = ,83740 = 56^{\circ} 52'$	
$2 \quad 59\frac{1}{2}$		$\text{Merid. zenith distance} = 33 \quad 8 \text{ S.}$	
$\text{Its half} = 1 \quad 29\frac{3}{4} \text{ tim. fr. n.}$		$\text{Declination} = 19 \quad 48 \text{ S.}$	
		$\text{True latitude} = 13 \quad 20 \text{ N.}$	

EXAM. III. Required the latitude of a place from the following observations made with a regulated watch and a Hadley's quadrant,

$$\left. \begin{array}{l} \text{Altitude } 41^{\circ} 53' \text{ at } 9 \text{ h. } 28 \text{ m. A. M.} \\ \text{Altitude } 44 \quad 54 \text{ at } 2 \text{ h. } 0 \text{ m. P. M.} \end{array} \right\} \text{interval } 4 \text{ h. } 32 \text{ m.} = 68^{\circ}.$$

$$\begin{array}{r} 86 \quad 47 \left| 43 \quad 23\frac{1}{2} = \frac{1}{2} \text{ sum of the altitudes: declination } 19^{\circ} 12' \text{ N.} \right. \\ 2) \quad \begin{array}{r} 3 \quad 1 \\ 1 \quad 30\frac{1}{2} \end{array} \left| \begin{array}{r} 1 \quad 30\frac{1}{2} \\ 1 \quad 30\frac{1}{2} \end{array} \right. \begin{array}{l} = \frac{1}{2} \text{ diff. altitudes: lat. by account } 59 \quad 0 \text{ N.} \\ \text{Ls, } \frac{1}{2} \text{ sum alts.} = 43^{\circ} 23\frac{1}{2}' \\ \text{Ls, } \frac{1}{2} \text{ diff. alts.} = 1 \quad 30\frac{1}{2} \\ \text{Ls, } \frac{1}{2} \text{ sum times} = 34 \quad 0 \\ \text{Ls, declinat.} = 19 \quad 12 \\ \text{Ls, latitude} = 59 \quad 0 \end{array} \end{array}$$

$9,86134$	$Ls, \text{ declinat.} = 19^{\circ} 12'$	$9,97514$
$8,42030$	$Ls, \text{ latitude} = 59 \quad 0$	$9,71184$
$0,25244$	$2Ls, \frac{1}{2} \text{ time} = 14 \quad 59$	$\left\{ \begin{array}{l} 9,41252 \\ 9,41252 \end{array} \right\}$
$0,02485$	$L, \frac{1}{2} \text{ correction} = ,03251$	$8,51202$
$0,28816$	$\text{Correction} = ,06502 \text{ to be added.}$	
$8,84711$	$s, \text{ altitude } 44^{\circ} 54' = ,70589$	
$4 \quad 2$	$s, \text{ merid. altitude } ,77091 = 50^{\circ} 26'$	
$\text{à noon at 1st alt.} = 38 \quad 2 = 2 \text{ h. } 32\frac{1}{2} \text{ m.}$	$\text{Hence the latitude} = 58 \quad 46 \text{ N.}$	
$\text{à noon at 2d alt.} = 29 \quad 58 = 1 \text{ h. } 59' 52''$		

EXAM. IV. Being by my dead reckoning in lat $30^{\circ} 30' N$. the declination being $10^{\circ} 24'$; the Sun's altitude in the forenoon was $61^{\circ} 47'$, and 5 hours after, in the afternoon, his altitude was $36^{\circ} 5\frac{1}{4}'$: Required the true latitude.

The interval, or diff. of time = 5h. | Altitudes $\left\{ \begin{array}{l} 61^{\circ} 47' \text{ nat. sine } ,88117 \\ 36 \quad 5\frac{1}{4} \end{array} \right.$
 diff. time 2h. 30m. = $37^{\circ} 30'$.

$$\begin{array}{r|l} 97 \quad 52\frac{1}{4} & 48 \quad 56\frac{1}{8} = \frac{1}{2} \text{ sum alt.} \\ \hline 25 \quad 41\frac{3}{4} & 12 \quad 51 = \frac{1}{2} \text{ diff. alta.} \end{array}$$

$$\begin{array}{lll} Ls, \frac{1}{2} \text{ sum alts.} & = 48^{\circ} 56\frac{1}{8} & 9,81750 \\ Ls, \frac{1}{2} \text{ diff. alts.} & = 12 \quad 51 & 9,34713 \\ Ls, \frac{1}{2} \text{ diff. times} & = 37 \quad 30 & 0,21555 \\ Ls, \text{ declinat.} & = 10 \quad 24 & 0,00720 \\ Ls, \text{ latitude} & = 30 \quad 30 & 0,06468 \end{array}$$

$$Ls, \frac{1}{2} \text{ sum times} = 16 \quad 27 \quad 9,45206$$

$$\text{à noon at 1st alt.} = 21 \quad 3 = 1h. 24\frac{3}{4}m.$$

$$\text{à noon at 2d. alt.} \quad 55 \quad 57 = 3h. 35\frac{1}{4}m.$$

$$1st \text{ altitude, at } 10h. \quad 35\frac{1}{4} \text{ min.}$$

$$2d \text{ altitude, at } 3h. \quad 35\frac{1}{4} \text{ min.}$$

$$\begin{array}{lll} Ls, \text{ declinat.} & = 10^{\circ} 24' & 9,99280 \\ Ls, \text{ latitude} & = 30 \quad 30 & 9,93532 \\ 2Ls, \frac{1}{2} \text{ times} & = 10 \quad 31 & \left\{ \begin{array}{l} 9,26165 \\ 9,26165 \end{array} \right. \end{array}$$

$$L \frac{1}{2} \text{ correct.} = ,02828 \quad 8,45142$$

$$\text{Correction} = ,05656 \text{ to be added.}$$

$$s, \text{ greatest alt.} = ,88117$$

$$s, \text{ merid. altitude } ,93773 = 69^{\circ} 40'$$

$$\text{Merid. zenith distance} = 20 \quad 20 S.$$

$$\text{Sun's declination} = 10 \quad 24 N.$$

$$\text{Latitude} = 30 \quad 44 N.$$

Second Operation.

$$\text{Sum of the 1st four logs.} \quad 9,38738$$

$$Ls, \text{ new lat. is} = 30 \quad 44 \quad 0,06573$$

$$Ls, \frac{1}{2} \text{ sum times} = 16 \quad 30 \quad 9,45311$$

$$\text{à noon at 1st alt.} = 21 \quad 0 = 1h. 24m.$$

$$\text{à noon at 2d alt.} = 54 \quad 0 = 3h. 36m.$$

$$1st \text{ altitude at } 10h. \quad 36m. \text{ A. M.}$$

$$2d \text{ altitude at } 3h. \quad 36m. \text{ P. M.}$$

$$Ls, \text{ declinat.} = 10 \quad 24 \quad 9,99280$$

$$Ls, \text{ new lat.} = 30 \quad 44 \quad 9,93427$$

$$2Ls, \frac{1}{2} \text{ time} = 10 \quad 30 \quad \left\{ \begin{array}{l} 9,26063 \\ 9,26063 \end{array} \right.$$

$$L, \frac{1}{2} \text{ correct.} = ,02808 \quad 8,44833$$

$$\text{Correction} = ,05616 \text{ to be added.}$$

$$s, \text{ greatest alt.} = ,88117$$

$$s, \text{ merid. alt.} = ,93733 = 69^{\circ} 39'.$$

Hence the true latitude will be $30^{\circ} 48' N$.

EXAM. V. Being by account in latitude $16^{\circ} 20' S.$ and the Sun's declination $22^{\circ} 48' S.$; at $8^h 31^m 44^s$ forenoon, the altitude of the Sun's center was $40^{\circ} 38'$; and at $1^h 17^m 44^s$ P. M. its altitude was $70^{\circ} 26'$: Required the true latitude.

Times $13 \ 17 \ 44$
 $8 \ 31 \ 44$

Alts. $70 \ 26$ Nat. sine $= 0,94225$
 $40 \ 38$

$4 \ 46 = 71^{\circ} 30'$; its $\frac{1}{2} = 35^{\circ} 45'$. $111 \ 4$; $\frac{1}{2}$ sum $= 55^{\circ} 32'$.

L. $\frac{1}{2}$ sum alts. $= 55 \ 32$

L. $\frac{1}{2}$ diff. alts. $= 14 \ 54$

L. $\frac{1}{2}$ sum times $= 35 \ 45$

L. $\frac{1}{2}$ declination $= 22 \ 48$

L. $\frac{1}{2}$ latitude $= 16 \ 20$

L. $\frac{1}{2}$ diff. times $= 16 \ 19$

Least time $= 19 \ 26$, its $\frac{1}{2} = 9^{\circ} 43'$.

9.75276

9.41016

0.23340

0.03534

0.01789

9.44955

$29 \ 48$; $\frac{1}{2}$ diff. $= 14 \ 54$.

L. $\frac{1}{2}$ declination $= 22^{\circ} 48'$ 9.96466

L. $\frac{1}{2}$ latitude $= 16 \ 20$ 9.98211

L. $\frac{1}{2}$ least time $= 9 \ 43$ 9.22731

L. $\frac{1}{2}$ least time $= 9 \ 43$ 9.22731

L. No. $\frac{1}{2}$ correct. $= 0,02520$ 8.40139

Correction $= 0,05040$ to be added.

N. $\frac{1}{2}$ gr. alt. $= 94225$

N. $\frac{1}{2}$ mer. alt. $= 99265 = 80^{\circ} 03'$

Mer. zenith distance $6 \ 57 S.$

Sun's declination $22 \ 48 S.$

Latitude $15 \ 51 S.$

Second Operation.

Sum of the four first logs.

L. $\frac{1}{2}$ latitude $= 15 \ 51$

L. $\frac{1}{2}$ diff. times $= 16 \ 18\frac{1}{2}$

$35 \ 45$

Least time $= 19 \ 26\frac{1}{2}$, its $\frac{1}{2} = 9^{\circ} 43\frac{1}{4}'$

9.43166

0.01683

9.44849

L. $\frac{1}{2}$ decl. $= 22^{\circ} 48'$ 9.96466

L. $\frac{1}{2}$ latitude $= 15 \ 51$ 9.98317

L. $\frac{1}{2}$ least time $= 9 \ 43\frac{1}{4}$ 9.22749

L. $\frac{1}{2}$ least time $= 9 \ 43\frac{1}{4}$ 9.22749

L. No. $\frac{1}{2}$ correct. $= 0,02528$ 8.40281

Correction $= 0,05056$ to be added.

N. $\frac{1}{2}$ gr. alt. $= 94225$

N. $\frac{1}{2}$ mer. alt. $= 99281 = 83^{\circ} 07'$

Hence the true latitude may be taken at $15^{\circ} 55' S.$

Suppose the latitude, declination, and altitudes the same as above; but the times had been at $8^h 31^m 44^s$, and $10^h 42^m 16^s$ in the forenoon; or at $1^h 17^m 44^s$ and $3^h 28^m 16^s$ in the afternoon; to correct the latitude by account.

Times $10^h 42^m 16^s$ Or $3^h 28^m 16^s$

$8 \ 31 \ 44$

$1 \ 17 \ 44$

$2 \ 10 \ 32$

$2 \ 10 \ 32$

$32 = 32^{\circ} 38'$; its $\frac{1}{2} = 16^{\circ} 19' = \frac{1}{2}$ diff. times.

Consequently, in the first part of the operation, if the $16^{\circ} 19'$ be used instead of $35^{\circ} 45'$; the sum of the five logs. will give the log. of $35^{\circ} 45'$, for the half sum of the times; and half the least time will be $9^{\circ} 43'$; therefore the same result will be obtained, and the final latitude will be $15^{\circ} 55' S.$

If three zenith distances, circumstanced as in Problem II. or III. could be taken, the latitude would be found with less trouble.

EXAM. VI. *Wanting to go through the 8° N. channel among the Maldives, and being by account in lat. 7° 20' N. with 22° 48' N. declination, at 7^h 25^m forenoon, I found the true altitude of the Sun's center was 22¹/₂°; and at 10^h 31^m 48^s its altitude was 63° 40': Required the ship's true latitude.*

Time 10^h 31^m 48^s
7 25 40

Alts 63° 40' N.s., 89623
22 30

Interval 3 6 8 = 46° 32'; its $\frac{1}{2}$ = 23° 16' 86 10; 43 05 = $\frac{1}{2}$ sum alt.

L's, $\frac{1}{2}$ sum alts. = 43° 05'	9,86354	L's, declinat. = 22 48	9,96467
L's, $\frac{1}{2}$ diff. alts. = 20 35	9,54601	L's, latitude = 7 20	9,99643
L's, $\frac{1}{2}$ diff. times = 23 16	0,40339	L's, $\frac{1}{2}$ l. time = 11 1 $\frac{1}{2}$	9,28157
L's, declination = 22 48	0,03533	L's, $\frac{1}{2}$ l. time = 11 1 $\frac{1}{2}$	9,28157
L's, declination = 7 20	0,00357	L, No $\frac{1}{2}$ correct. = ,03344	8,52424
L's, latitude = 7 20	9,85184	Correction = ,06688	
Least tim. à noon = 22 3, its $\frac{1}{2}$ = 11° 1 $\frac{1}{2}$ '		N.s, gr. alt. = ,89623	
		N.s, merid. alt. = ,96311 = 74° 23'.	
		Mer. zen. dist. = 15 37N	
		Declination = 22 48N.	
		Latitude = 7 11N.	

Second Operation.

Sum of the four first logs. = 9,84827	L's, decl. = 22° 48'	9,96467
L's, latitude = 7° 11'	L's, latitude = 7 11	9,99658
L's, $\frac{1}{2}$ sum times 45 17 $\frac{1}{2}$	L's, $\frac{1}{2}$ l. time = 11 0 $\frac{3}{4}$	9,28108
$\frac{1}{2}$ diff. times 23 16	L's, $\frac{1}{2}$ l. time = 11 0 $\frac{3}{4}$	9,28108
Least time à noon 22 1 $\frac{1}{2}$, its $\frac{1}{2}$ = 11° 0 $\frac{3}{4}$ '	L, No $\frac{1}{2}$ correct. = ,03337	8,52341
	Correction = ,06674	
	,89623	
	N.s, mer. alt. = ,90297 = 74° 21'.	
	Hence the latitude is 7° 9' N.	

If the altitude had been at 1^h 28^m 12^s, and at 4^h 34^m 20^s, both afternoon, the latitude would have been the same.

But had the times been at 7^h 25^m 40^s forenoon, and at 1^h 28^m 12^s afternoon: or, at 10^h 31^m 48^s forenoon, and at 4^h 34^m 20^s afternoon, with the same altitudes, declination, and latitude, by account, to correct the latitude.

Times 13^h 28^m 12^s
7 25 40

Or 16^h 34^m 20^s
10 31 48

6 2 32 sum of the times

6 2 32

3 1 16 = 45° 19'

Then the log. of 45° 19' being used for the third log. instead of that of 23° 16', the sum of these five logs. will be the log. of 23° 16', the half difference of the times; and, consequently, the least time will be the same as in the former operation; and the final result for the latitude will be the same.

EXAM.

EXAM. VII. *Wanting to make the English Channel, I observed the true altitude of the Sun's center $24^{\circ} 30'$, and $3^h 4^m$ after, its altitude was $52^{\circ} 16'$; our latitude by account was $49^{\circ} 12'$, and the Sun's declination 23° : Required the ship's true latitude.*

$3^h 4^m = 46^{\circ}$; its $\frac{1}{2} = 23^{\circ}$ the $\frac{1}{2}$ interval. 2d alt. $= 52^{\circ} 16'$ Nat. sine 79087
1st alt. $= 24^{\circ} 30'$

		76 46	38° 23'
		2 —	
		27 46	13 53
L, $\frac{1}{2}$ sum alts. $= 38^{\circ} 23'$	9,89425	L, declination $= 23^{\circ} 0'$	9,96403
L, $\frac{1}{2}$ diff. alts. $= 13^{\circ} 53'$	9,38011	L, latitude $= 49^{\circ} 12'$	9,81519
L, $\frac{1}{2}$ interval $= 23^{\circ} 0'$	0,40812	L, $\frac{1}{2}$ least time $= 15^{\circ} 4\frac{1}{2}'$	9,41512
L, declination $= 23^{\circ} 0'$	0,03597	L, $\frac{1}{2}$ least time $= 15^{\circ} 4\frac{1}{2}'$	9,41512
L, latitude $= 49^{\circ} 12'$	0,18481	L, No $\frac{1}{2}$ correct. $= 04069$	8,60946
		Correction	08137
L, $\frac{1}{2}$ sum times $= 53^{\circ} 09'$	9,90326		<u>$= 79087$</u>
Last time à noon $= 30^{\circ}$		N, mer. alt. $= 87224 = 60^{\circ} 43'$	
9, its $\frac{1}{2} = 15^{\circ} 4\frac{1}{2}'$		Zen. dist. $= 29^{\circ} 17'$	
		Decl. $= 23^{\circ} 0'$	
		Latitude $52^{\circ} 17'$	

Second Operation.

Sum of four first logs.	9,71845	L, decl. $= 23^{\circ} 0'$	9,96403
L, latitude $= 52^{\circ} 17'$	0,21342	L, latitude $= 52^{\circ} 17'$	9,78658
L, $\frac{1}{2}$ sum times $= 58^{\circ} 44'$	9,93187	L, $\frac{1}{2}$ l. time $= 17^{\circ} 52'$	9,48686
		L, $\frac{1}{2}$ l. time $= 17^{\circ} 52'$	9,48686
Least time à noon $35^{\circ} 44'$, its $\frac{1}{2} = 17^{\circ} 52'$		L, No $\frac{1}{2}$ correct. $= 05301$	8,72433
Latitude $52^{\circ} 17'$ first found.			10602
Latitude $49^{\circ} 15'$ second found.			<u>79087</u>
			<u>$89689 = 63^{\circ} 45'$</u>
			Zen. dist. $26^{\circ} 15'$
			Decl. $23^{\circ} 0'$
Mean latitude $50^{\circ} 46'$			Latitude $49^{\circ} 15'$

Third Operation.

Sum of four first logs.	9,71845	L, decl. $= 23^{\circ} 0'$	9,96403
L, latitude $= 50^{\circ} 46'$	0,19895	L, latitude $= 50^{\circ} 46'$	9,80105
L, $\frac{1}{2}$ sum times $= 55^{\circ} 46'$	9,91740	L, $\frac{1}{2}$ least time $= 16^{\circ} 23'$	9,45034
		L, $\frac{1}{2}$ least time $= 16^{\circ} 23'$	9,45035
Least t. à noon $= 32^{\circ} 46'$, its $\frac{1}{2} = 16^{\circ} 23'$		L, No $\frac{1}{2}$ correct. $= 04632$	8,66577
			09264
			<u>79087</u>
		N, mer. alt. $= 88351 = 62^{\circ} 04'$	
		Zen. dist. $37^{\circ} 56'$	
		Decl. $23^{\circ} 0'$	
		Latitude $50^{\circ} 56'$	
		Former mean latitude $50^{\circ} 46'$	
			<u>10142</u>
		True latitude $50^{\circ} 51'$	

In the preceding Problem it was supposed that both the altitudes were taken at the same place; but as this can seldom happen at sea, it is necessary to shew how the latitude may be obtained when the altitudes are observed at two different, but not very distant places.

75.

P R O B L E M VII.

Given the latitude by account, the Sun's declination, two observed altitudes, the interval of time, and the course and distance run, between the observations; to find the latitude corresponding with the noon of that day.

SOLUTION.

1st. Find the latitude by account at the time, when the greater altitude was taken.

2d. Let the bearing of the Sun be taken by the compass at the instant when the least altitude was observed, and take the difference between that bearing and the ship's course by compass.

3d. With this angle, or its supplement, if more than 90 degrees, and the distance run by the ship between the observations, find the difference of latitude in the traverse table.

4th. This difference of latitude must be added to the first altitude, if the angle between the Sun and ship's tract be less than 90° ; but it must be subtracted from it, if that angle be greater than 90° , to give the first altitude, as it would have been found, if it had been observed at the same place where the second was.

5th. With these altitudes (thus reduced to the same zenith), the observed interval of time, together with the declination and the latitude by account, at the greatest altitude, find the meridian altitude by the preceding problem; and hence the latitude will be obtained for the time, when the greater altitude was observed.

6th. If the latitude be required for noon, with the courses run by the ship, corrected for variation of the compass and lee-way (32, 35,) and her distance run by the log. find the difference of latitude made good from the time when the greater altitude was observed at noon; which being applied to the latitude, found above, at the time of the greater altitude, will give the latitude at noon.

REMARK. If the Sun's bearing could be taken with sufficient accuracy at either observation, it would render the other observation useless; for, with the azimuth, the polar distance and the zenith distance, taken at any time, the latitude and hour from noon may be found. But although the Sun's azimuth cannot be observed with sufficient exactness for this purpose, it may for obtaining the correction to be applied to one of the altitudes to reduce it to what it would have been found, if it had been taken where the other was. For the small error incident to the correction of the zenith distance, by being computed from an azimuth somewhat erroneous, will bear to the error in that azimuth, a ratio but little different from that of the sine of the distance run by the ship to the co-secant

co-secant of the angle which the ship's course makes with the azimuth circle that the Sun was on*. Or, instead of observing the sun's azimuth, it may be computed from the latitude by account, sufficiently exact for the purpose of obtaining this correction, as was proposed by Dr. Pemberton.

Note. In the second operation of the Examples to the VIth and VIIth Problems, the arith. compl. of the co-sine of the latitude is added to the sum of the four first logarithms, according to the precept in Problem VI. by which means the conformity of the second operations with the first is more expressly shewn; yet the same logarithm would be produced by deducting the co-sine of the latitude from the said sum.

EXAM. I. *Sailing S. E. 11 knots an hour, at 9^h 36^m forenoon, the true altitude of the Sun's center was 52° 2', and his bearing was S. 60° 30' E. and at 11^h 24^m, his altitude was 63° 45'; the latitude by account at this time being 48° 46' N. and the Sun's declination 23° 20' N. : Required the latitude at the time when the latter altitude was observed.*

Now 11^h. 24^m. — 9^h. 36^m. = 1^h. 48^m. is the interval of time.

And 1^h. : 1^h. 48^m. :: 11kn. : 20kn. nearly the dist. run in 1^h. 48^m.

Also 60° 30' the Sun's rhumb, lessened by 45° the ship's rhumb, leaves 15° 30' for the diff. of rhumbs.

Then with the course 15° 30', and dist. 20m. the diff. lat. is 19m.

And 52° 2' + 19' = 52° 21' for the lesser altitude corrected; or fitted to the zenith where the greatest altitude was taken.

Now 1 ^h . 48 ^m . = 27° 0'	Alts. 63° 45' N. S. 89687		
half interval = 13 30	52 21 N. S. 79176		
	half sum 58 3; half diff. 5° 42'		
Ls $\frac{1}{2}$ sum alts. = 58° 03'	9,72360	Ls declin. = 23° 20'	9,96294
Ls $\frac{1}{2}$ diff. alts. = 5 42	8,99704	Ls lat. = 48 46	9,81897
Ls $\frac{1}{2}$ diff. times = 13 30	0,63182	Ls, $\frac{1}{2}$ l. time = 4 10	8,86128
Ls declination = 23 20	0,03706	Ls, $\frac{1}{2}$ l. time = 4 10	8,86128
Ls lat. = 48 46	0,18103	L. N° $\frac{1}{2}$ corr. = ,003195	7,50447
		Correction = ,00639	
Ls $\frac{1}{2}$ sum times = 21 50	9,57055	N. least alt. = ,89687	
Lr. time à noon = 8 20, its $\frac{1}{2}$ = 4 10		N. mer. alt. = ,90326 = 64 35	
		mer. zen. dist,	25 25 S.
		Declin.	23 20 N.
		Lat.	48 45 N.

Here the lat. 48° 45' computed, differing by 1 minute only from the latitude by account, may be taken for the true latitude.

* *Cotes. Æstim. Eur. in Mixt. Math. Theorem. 22.*

EXAM. II. Being by account in latitude $51^{\circ} 6' N.$ when the Sun's declination was $22^{\circ} 23' S.$; at 9h. 18m. A. M. the Sun's altitude was $8^{\circ} 37\frac{1}{2}'$, when he bore S. $36^{\circ} 45' E.$; and having run NW. b. W. eight knots an hour, at 10h. 40m. the Sun's altitude was $14^{\circ} 46'$: Required the latitude at the time when the second observation was taken.

Here the observed difference of time is 1h. 22m.

Now 1h. : 1h. 22m. :: 8kn. : : 11nk. nearly the dist. run betw. the obs.

Here the Sun's rhumb. is S. $36^{\circ} 45' E.$

And the ship's rhumb. is N. $56^{\circ} 15' W.$

The angle comprehended between them is $160^{\circ} 30'$.

Its supplement is $19^{\circ} 30'$, which as a course, with the dist. 11, gives $10\frac{1}{2}$ for a diff. lat.

And the ship running northward from the Sun lessens the altitude.

Then $8^{\circ} 37\frac{1}{2}' - 10\frac{1}{2}' = 8^{\circ} 27'$ is the alt. to be used at the 2d observation.

To find the latitude by Problem VII.

10h. 40' } interval=1h. 22m.=20° 30'.	Alts. { 14° 46' ½ sum = 11° 36½'.		
9 18 } half diff. times=10 15	{ 8 27 ½ diff. = 3 9½.		
Ls, ½ sum alts. = 11° 36½'	9,99102	Ls, declination 22° 23'	9,96598
Ls, ½ diff. alts. = 3 9½	8,74111	Ls, latitude 51 6	9,79793
Ls, ½ diff. times = 10 15	0,74972	2Ls, ¼ time 10 37	8,53075
Ls, declination = 22 23	0,03402		
Ls, latitude = 51 6	0,20207	L, ½ correction	0,019705 8,29466
Ls, ½ sum times = 31 29	9,74794	Correction	0,03941
		Nat. sine	0,25488 of 14° 46'
Least time 21 14 from noon.			
		s, of 17° 07'	0,29429 merid alt.
		And 72 53=merid. zen. distance,	

Then $72^{\circ} 53' - 22^{\circ} 23' = 50^{\circ} 30' N.$ is the latitude.

(60)

Second Operation.

Sum of the four first logs.	9,51587	Ls, declination = $22^{\circ} 23'$	9,96598
Ls, latitude $50^{\circ} 30'$	0,19649	Ls, latitude = $50^{\circ} 30'$	9,80351
		2Ls, $\frac{1}{2}$ least time 10 24	8,51305
Ls, $\frac{1}{2}$ sum times 31 34	9,71236		
Least time 20 48 fr. noon.		L, $\frac{1}{2}$ correction 0,019165	8,28954

Then the correction $0,03833 + 0,25488$ the nat. fine of $14^{\circ} 46'$ gives $0,29321$ the nat. fine of $17^{\circ} 03'$ the merid. alt. and the merid. zen. dist. = $72^{\circ} 57'$.

Therefore the latitude will be $50^{\circ} 34' N.$

And by making a third operation, the latitude sought will be found to be $50^{\circ} 34' N.$ The same to a mile as it was before.

EXAM.

EXAM. III. *Running with a brisk gale ten knots an hour, on a W. S. W. course; at 10^h 36^m forenoon, the altitude of the Sun's center was observed to be 61° 47'; and at 3^h 36^m P. M. his altitude was again found to be 36° 5', and his bearing S. 80° 30' W. by our account, the latitude at 10^h 36^m was 30° N. and the Sun's declination 10° 24' N.: Required the latitude at the time of the first observation.*

Here the observed difference of time is five hours.

And 1h : 5h :: 10kn : 50kn. the distance run between the observations.

When, as in this case, the Sun's bearing is taken at the second observation, the opposite point to the ship's course must be used in reducing that altitude to the same situation with the first.

Now the Sun's rhumb is S. 80° 30' W. or N. 80° 30' E.

And the opposite point to the ship's course, is N. 67 30 E.

Their diff. is 13° 08', which as a course, with the dist. 50, gives diff. lat. 49^m. Then 36° 5' - 49' = 35° 16'.

Then 36° 5' - 49' = 35° 16' is the corrected alt. for the 2d observation.

To find the latitude by Problem VII.

Interval 5h. = 75° 0'	Alts. 61° 47'	$\frac{1}{2}$ sum alts. = 48° 31 $\frac{1}{2}$ '	
$\frac{1}{2}$ Interval = 37 30	35 16	$\frac{1}{2}$ diff. alts. = 13 15 $\frac{1}{2}$ '	
L _s , $\frac{1}{2}$ sum alts. = 48° 31 $\frac{1}{2}$ '	9,82105	L _s , decl. = 10° 24'	9,99281
L _s , $\frac{1}{2}$ diff. alts. = 13 15 $\frac{1}{2}$ '	9,36048	L _s , latitude = 30 0	9,93753
L _s , $\frac{1}{2}$ sum times = 37 30	0,21555	L _s , $\frac{1}{2}$ time = 10 14	9,24958
L _s , decl. = 10 24	0,00719	L _s , $\frac{1}{2}$ time = 10 14	9,24958
L _s , latitude = 30 0	0,06247	L, N° $\frac{1}{2}$ corr. = 0,026885	8,42950
		Correction = 0,05377	
L _s , $\frac{1}{2}$ diff. times = 17 2	9,46674	N _s , of 35 16 = 88117	
		N _s , mer. alt. = 93494 = 69° 13'	
Lea. time à noon = 20 28; its $\frac{1}{2}$ = 10° 14'		And the latitude at noon 31° 11' N. (61)	

By a 2d operation the latitude will be found to be 31° 26' N. by a 3d 31° 30' N., and by a 4th 31° 30' N.

By working with the latitude 29° 41', which the ship was in at the 2d observation, the final result will be the same, as is shewn in the following practical form of placing the work of these Examples: 9,40427 is the sum of the four first logarithms.

First Operation.		Second Operation.		Third Operation.	
9,40427	9,99281	9,40427	9,99281	9,40427	9,99281
0,06109	9,93891	0,06724	9,93276	0,06869	9,93131
9,46536	9,66056	9,47151	9,66240	9,47296	9,66289
16° 58 $\frac{1}{2}$ '	9,66056	17° 13 $\frac{1}{2}$ '	9,66240	17° 17'	9,66289
37 30	9,25284		9,2537		9,24990
	17900	37 30	0,17798	37 30	0,17779
54 28 $\frac{1}{2}$	0,35800	54 43 $\frac{1}{2}$	0,35596	54 47	0,35558
27 14 $\frac{1}{4}$	0,57740	27 21 $\frac{1}{4}$	0,57740	27 23 $\frac{1}{4}$	0,57740
	93540		9,3336		9,3298
Mer. alt.	69° 18'	Mer. alt.	68° 58'	Mer. alt.	68° 54'
Zen. dist.	20 42	Zen. dist.	21 02	Zen. dist.	21 6
Decl.	10 24	Decl.	10 24	Decl.	10 24
Latitude	31 6	Latitude	31 26	Latitude	31 30 N.

EXAM.

EXAM. IV. *January 20, 1780, being by account in latitude $56^{\circ} 30'$ S. longitude $64^{\circ} W$. at 7h. 32m. and at 10h. 28m. forenoon, by fore observations, the altitudes of the Sun's lower limb, were $29^{\circ} 47\frac{1}{2}'$, and $49^{\circ} 52\frac{1}{4}'$; and his bearing at the former N. $80^{\circ} E$. the eye 20 feet above the water, and between the observations the ship had run 8 knots an hour, on a course S. $50' E$.: Required the mid-day latitude.*

Now ship time $19^h 32^m$ P.M. + $4^h 16^m$ W. = $23^h 58^m$. Or, $11^h 58^m$ A.M. London.

Or, $22^h 28^m$ P.M. + $4^h 16^m$ W. = $26^h 44^m$. Or, $2^h 44^m$ P.M. Lond. time. (57.)

The Sun's declination fitted to these times, are $20^{\circ} 8'$, and $20^{\circ} 7'$. (V. 281.) (57.)

App. alt. $\odot$ lower edge	29 47 30	And, 49 52 45
$\odot \frac{1}{2}$ diameter +	16 20	16 20
App. alt. $\odot$ center	30 3 50	50 9 05
Dip. on 20 feet	4 15	4 15
	29 59 35	50 4 50
Refraction	1 38	48
True alt. $\odot$ center	29 57 57	50 4 2
Or,	29 58	50 4

Now the interval is $2^h 56^m$. And $1^h : 2^h 56^m :: 8kn : 23kn$: the distance run.

With the course S. $50' E$. and distance 23^m the diff. lat. is 15^m .

Then $56^{\circ} 30' + 15' = 56^{\circ} 45'$ the latitude in at second observation.

Again. The difference between the Sun's bearing N. $80' E$. and the ship's course N. $130^{\circ} E$. gives 50° .

And with the course 50° and dist. 23^m the diff. lat. is 15^m .

So $29^{\circ} 58' + 15' = 30^{\circ} 13'$ the corrected alt. at 1st observation.

The interval = $2^h 56^m = 44^{\circ}$ Alt. $50^{\circ} 4'$ | $\frac{1}{2}$ sum alts. = $40^{\circ} 08\frac{1}{2}'$
 Its half = 22 | $\frac{1}{2}$ diff. alts. = $9^{\circ} 55\frac{1}{2}'$

First Operation.		Second Operation.		Third Operation.	
9.88335	9.97262	9.57363	9.97262	9.57363	9.97262
9.23643	9.74189	0.26331	9.73669	0.26157	9.73843
0.42647	9.72873	9.83694	9.73249	9.83520	9.73126
0.22738	9.72873	43° 23'	9.73249	43° 10 $\frac{1}{2}'$	9.73126
0.25811	9.17197	22	9.17429	22	3.17357
9.85174	.14860	65 23	.14940	65 10 $\frac{1}{2}$	.14910
42° 45'	.29720	32 41 $\frac{1}{2}$		32 35 $\frac{1}{2}$	.29820
22	.50327	Correction,	29880		.50327
64 45	.80047	Least alt.	.50327		.8014
32 28 $\frac{1}{2}$	53° 11'	Mer. alt.	.80207	Mer. alt.	53° 16'
Zen. dist.	36 49 N.	Mer. alt.	53° 20'	Mer. zen. dist.	36 44
Decl.	20 8 S.	Zen. dist.	36 40	Declination	20 8
Latitude	56 57	Declination	20 8	Latitude	56 52
		Latitude	56 48		

But working with the latitude $56^{\circ} 45'$, and the declination $20^{\circ} 7'$, at the second observation.

First Operation.		Second Operation.	
9,88330	9,97266	9,57354	9,97266
9,23643	9,73901	0,26215	9,73785
0,42647	9,73081		
0,02734	9,73081	9,83569	9,73160
0,26099	9,17329	$43^{\circ} 14'$	9,73160
9,83453	,14904	22	9,17371
$43^{\circ} 06'$	Cor. ,29808	65 14	N ^o ,14920
22 00	,50327		
		32 37	Corr. ,29840
65 06	,80135		
		N.s, least alt.	,50327
32 33			
Mer. alt.	$53^{\circ} 16'$	N.s, mer. alt.	,80167
Zen. dist.	36 44 N.	Merid. alt.	$53^{\circ} 17'$
Declination	20 07 S.		
		Zen. dist.	36 43 N.
Latitude	$56^{\circ} 51 S.$	Declination	20 07 S.
		Latitude	$56^{\circ} 50 S.$

Hence it appears, that in the work of such examples as the preceding, it is almost indifferent, whether the latitude by account and declination relates to the observation nearest to noon, or farthest from noon. However, for the sake of uniformity, it may be recommended to use the latitude, the declination, and the natural sine, which do all relate to the same altitude.

It will be shewn in the Appendix how this problem was considered by *Facio*; but his solution requiring too many trigonometrical operations to be of ready use, the preceding method by approximation was substituted instead thereof.

76. Mr. *Richard Graham's* method of solving this problem, published in the Philosophical Transactions for the year 1734, N^o 435, by a kind of instrumental operation, may indeed give the latitude within some minutes of the truth with ease and expedition: it is, in substance, as follows:

Description of the Instrument.

To the meridian of a globe (properly divided) let a piece of a like meridian, called the beam compass, about 110 degrees long, and divided like the former, be fitted, and made to slide on the upper side of the meridian*. Moreover let two sliding Vernier's scales be fitted to

* In Mr. *Graham's* instrument, made on purpose for this problem, the beam compass slides under the meridian.

those

those circles, dividing each degree into every five minutes. The beam compass must be so applied, that a pin, on which it turns as a center, and fixed exactly at 0 degrees, or one end of it, may pass through a hole at the beginning of the divisions of the Vernier which is to slide on the meridian, that pin serving as the center of motion of the beam compass, when the Vernier is screwed to the meridian: the other Vernier is to slide on the beam compass, and carry with it a pointer, or index, at the beginning of its divisions.

With this Instrument the problem is thus solved:

At the time of the first observation, let the Sun's bearing be also observed, and take the difference between the rhumbs on which the Sun was observed, and the rhumb on which the ship steered between the observations: Then say,

As radius is to the co-sine of that difference of rhumbs, so is the distance run between the observations, to the minutes of correction to be applied to the first zenith distance, and is to be added when the ship sails from the Sun, otherwise it is to be subtracted.

Then slide the Vernier's scale on the meridian to the given declination, and the Vernier on the beam compass to the first zenith distance as corrected, and let these scales be fixed by their screws. Rectify the globe for noon (VI. 59), turn it till the hour-index points at the time of the first observation; there hold the globe fast, and move the beam compass on its center, nearly into the azimuth of the Sun at that observation, and describe an arc on the globe with the pointer of the Vernier.

Slide the Vernier on the beam compass to the second observed zenith distance; turn the globe (the proper way) till the hour-index points at the time of the second observation; there hold the globe fast, and with the beam compass cut the former arc, their intersection will shew the place of the ship at the time of the second observation: bring the meridian over that point, and the latitude is found; also the hour-index will point at the true time of the day when the last observation was made.

SECTION X.

77. *To find the Longitude at Sea.*

If an accurate account could be kept of the true courses which a ship has steered, as directed by the compass, and of the distance she has run, as measured by the log, or by any other contrivance; then both the latitude and longitude of the place where the ship is at any time, would be known on settling the ship's account to that time.

For the course and distance being known, the difference of latitude and departure is readily found by the traverse table; and the difference of longitude being also found (VIII. 60), the true lat. and longitude are known.

But as the ship's motion is liable to be disturbed from a variety of causes, such as, a continual deflection from the course set, by the ship's playing to the right and left round her center of gravity, and the unequal care of the helmsmen: and the distance sailed being faulty, on account of tumbling seas rolling with or against the ship; the unsteadiness of the wind; unknown currents; sudden storms, and many other circumstances, which seem impossible to be allowed for; her place, assigned by these means, may justly be suspected to be erroneous. Mariners judge of this by finding the ship's latitude every day, if they can, by observations of the Sun or Stars; and if the latitude, found by their reckoning, agrees what that found by observation, it is presumed that the ship's place is well determined: but if they disagree, they conclude that the account of longitude stands in need of correction; the latitude found by observation being always to be depended on.

78. The error in the ship's reckoning is frequently attributed to unknown currents. For, from causes yet undetermined, there are many and various motions of the water in the open seas, as well as those observed near the shores, where the motions may be tolerably well accounted for. Some of the currents observed in the great seas may perhaps be owing to the tide's following the Moon, and to the libratory motion which the waters may derive from thence; and the unsettled setting and drift of these currents may possibly depend on the change in the Moon's declination. However, it is well known from observations, that the trade-winds occasion a considerable current within their limits, particularly within the Torrid Zone, where the motion is perpetually towards the west, at the rate of 8 or 10 miles a day. But at the extremities of the trade-winds, or near the latitudes of 30 degrees north or south, it is likely, that the currents are compounded of the said western motion, and of one toward the equator (by observation 2. Art. 84. B. VI.): therefore all ships, sailing within these limits, should allow a course each day for this current.

Although some of the methods recommended for correcting a sea reckoning are little better than guess-work, as it cannot be known with certainty whether the ship is to the eastward or westward of the point in which the reckoning places her; yet it was judged proper to introduce them here, as they may sometimes be useful.

Methods of Correcting the Reckoning of Longitude.

79. METHOD I. *When the error is supposed to happen from a current.*

Consider whether the difference may not have been occasioned by a current, and, if it is possible, try it (by Article 47, Book VII.) ; or make such an estimate of its setting and drift, as may be judged reasonable. Then with the setting and drift, as a course and distance, find the difference of latitude and departure, with which increase or diminish the dead reckoning ; and if the latitude, thus corrected, agrees with the latitude by observation, the departure, thus corrected, may be safely taken as true, and so the ship's place determined with regard to longitude.

EXAM. I. *Suppose a ship in 24 hours finds by her dead reckoning, she has made 96 miles of diff. lat. N., and 38 miles of departure W.; but by observation, finds her difference of latitude is 112, and on trial finds a current, which in 24 hours makes 16 miles of diff. lat. N., and 10 miles of depart. E.: What is the ship's departure?*

Diff. lat. by account	96 m. N.	Departure by account	38 m. W.
Diff. lat. by current	16 m. N.	Departure by current	10 m. E.
True diff. lat.	112 m. N.		28 m. W.

Here the dead reckoning corrected by the current gives the difference of latitude 112 miles, which is the same as found by observation ; therefore the departure 28 is taken as the true one.

EXAM. II. *Yesterday noon we were in latitude $36^{\circ} 15' N.$, and have sailed these 24 hours, 1st. $SE. \frac{1}{2} E.$ 55 m. 2d. $NE. by N.$ 20 m. 3d. $WSW.$ 70 m. 4th. $S. by W. \frac{1}{2} W.$ 20 m. and all the time in a current setting $SSW. \frac{1}{4} W. \frac{1}{8} m.$ an hour : By an observation this day at noon, we were in latitude $34^{\circ} 58' N.$: Required the true departure the ship has made?*

Courses.	Dist.	N.	S.	E.	W.
$SE. \frac{1}{2} E.$	55		34,9	42,5	
$NE. by N.$	20	16,6		11,4	
$WSW.$	70		26,8		64,7
$S. by W. \frac{1}{2} W.$	20		19,1		5,8
$SSW. \frac{1}{4} W.$	15		12,8		7,7
		16,6	93,6	53,6	78,2
		diff. lat.	77,0	dep.	24,6

Departed lat. $36^{\circ} 15' N.$
Present lat. $34^{\circ} 58' N.$

Diff. latitude $1^{\circ} 17' = 77 m.$

Here the current being taken into the account, produces a diff. lat. by dead reckoning equal to that found by observation ; and therefore the departure by the dead reckoning is taken as the true departure.

80. METHOD II. *When the error is thought to arise from the courses and distances.*

If the difference of latitude is much more than the departure, or the direct course has been within three points of the meridian; it is most likely the error is in the distance.

And if the departure is much greater than the difference of latitude, or the direct course is within three points of the parallel, or more than five points from the meridian, the error may be ascribed to the course.

But if the courses are in general near the middle of the quadrant, the error may be either in the course, or in the distance, or in both.

For, to cause an alteration in the difference of latitude, the first of these cases requires a greater error in the course than can well be supposed to have been committed; in the second case, the distance must be so faulty as would scarce escape observation; and in the last, it is often doubtful whether to attribute the error to the course or distance; but it is usually corrected in both.

81.

CASE I.

When, by the dead reckoning, the diff. lat. is more than once and a half the departure: Or, which is the same, when the course is less than three points.

RULE. To the diff. lat. and the departure by account, find the course.

With this course, and the meridional diff. lat. by observation, find the diff. of long.

EXAM. Yesterday noon we were in lat. $39^{\circ} 18' N.$, and by an observation are this day noon in lat. $37^{\circ} 48' N.$; our dead reckoning gives 116 miles of southing, and 64 miles of easting: Required the ship's true difference of long.

By the TRAVERSE TABLE.

The diff. lat. 116, and the departure 64, gives the course 29 degrees.

The course 29 degrees, and the meridional diff. lat. by observ. 115, gives the diff. long. 64.

82.

CASE II.

When by the dead reckoning the departure is more than once and a half the difference of latitude: or, the course is more than five points.

RULE. With the diff. of latitude by observation, and departure by account, find the course and distance.

With the co-mid. latitude by observation, and depart. by account, find the diff. longitude.

EXAM. Yesterday noon we were in latitude $48^{\circ} 52' N.$, and were to-day at noon in latitude $50^{\circ} 18' N.$; our dead reckoning shews we have made 68 miles of northing, and 112 miles of westing: Required the true difference of longitude the ship has made.

By the TRAVERSE TABLE.

The diff. lat. 86 and departure 112, gives $52\frac{1}{2}^{\circ}$ for the course, and 131 for the distance.

The co-mid. latitude $40^{\circ} 25'$, and the departure 112, give 173 miles for difference of longitude.

83.

CASE III.

When the difference of latitude and departure by account is nearly equal, or the direct course has been between three and five points of the meridian.

RULE. With the diff. of latitude and departure by account, since the last observation, find the course.

With this course, and the diff. of lat. by observation, find another departure.

Take half the sum of these two departures for the true one.

With the true departure and diff. of lat. by observations, find the true course.

With the true course and meridional diff. of lat. by observation, find the diff. of longitude.

EXAM. *The last 24 hours we have made 84 miles of northing, and 76 of easting; we were yesterday noon in latitude $52^{\circ} 40'$ N., and are this noon in latitude $54^{\circ} 22'$ N.: What difference of longitude has the ship made?*

By the TRAVERSE TABLE.

To the diff. latitude 84 and departure 76, the course is 42° .

With the course 42° and diff. lat. by observ. 102, find the departure 91,8.

The sum of the two departures 76 and 91,8 is 167,8, its half is 83,9.

With dep. 83,9, and diff. of lat. by observ. 102, find the course 39° .

With this course and 171,6, the merid. diff. of lat. find 139, the diff. long.

84. Dr. Halley, having collected a great multitude of observations made on the variation of the needle in many parts of the world, was enabled, by the help of the latitudes and longitudes of the places of those observations, to draw certain lines on a Mercator's chart, shewing the variation of the compass in all the places over which they passed, in the year 1700, the time he published the first chart of this kind, called the Variation Chart. Consequently, the longitude of any of those places could be found by the chart, having its latitude and the variation of the needle in that place given.

85. METHOD III. *To find the longitude at sea by the variation chart.*

Find the variation of the compass: for which see Article 28.

Draw a parallel of lat. on the chart through the lat. found by observ.

And the point where it cuts the curved line, which is marked with the variation that was observed, will be the ship's place.

EXAM. *A ship finds, by a good observation, that she is in the latitude of $18^{\circ} 20'$ N.; and that the variation of the compass is 4° west: Required the ship's place.*

Lay a ruler over $18,20$ N. parallel to the equator, and the point where its edge cuts the curve of 4° west variation, gives the ship's place, which will be found in about longitude $27^{\circ} 10'$ west from London.

86. This method is attended with two inconveniencies.

First, That wherever the variation lines run east or west, or nearly so, this way of finding the longitude becomes imperfect. But this imperfection is at present found chiefly on the west coasts of Europe, between the latitudes of 45° and 53° ; on the eastern shores of North America, and in some parts of the Western Ocean and Hudson's Bay; there-

therefore, for the other parts of the world, a variation chart may be esteemed of great use.

87. But the variation curves, even where they run east and west, may be sometimes applied to good use in correcting the latitude, when meridian observations cannot be had, as it frequently happens on the northern coasts of America, in the Western Ocean, and about Newfoundland. For if the variation can be obtained exactly, the east and west curve answering to that variation on the chart will shew the latitude.

Secondly, As the deflection of the magnetical meridian from the true one is subject to continual alteration, a chart to which the variation lines are suited for any year, must in time become useless, unless new lines, shewing the state of the variation at that time, be drawn on that chart. But as the change in the variation is very slow, if new variation charts were published every seven or eight years, it would fully answer the purpose wanted.

88. Notwithstanding the great use which Dr. Halley's Variation Chart afforded to most mariners, yet it has been almost useless, for want of public encouragement to renew it from time to time. However, in the year 1746, Mr. William Mountaine, F. R. S. and Mr. James Dodson, published a new Variation Chart, fitted for that year, which was well received; and several instances of its great utility having been communicated to them, they drew the Variation lines again for the year 1756, and the year following published the third Variation Chart. They also presented to the Royal Society a curious paper concerning the variation of the magnetic needle, with a set of tables annexed, containing the result of upwards of fifty thousand observations, in six periodical reviews, from the year 1700 to 1756, inclusive, and adapted to every five degrees of latitude and longitude, in the more frequented oceans: which paper and tables were printed in the Society's Transactions for the year 1757.

The engraving of new plates on every publication of such charts, is a charge too great for private persons to incur; and should, like the Nautical Almanac, be done at the expence of the public; especially as the use of it is so easy, and so well suited to the knowledge and time of mariners in general.

89. METHOD IV. *To find the longitude by the help of a perfect time-keeper.*

This method is a mechanical solution of the following problem.

The time in any unknown place, relative to the meridian of that place, being given, to find what o'clock it is, at that instant, under the meridian of some known place; suppose London or Greenwich.

If a clock or watch were so contrived, as to go uniformly in all seasons and in all places; such a watch, being regulated to London or Greenwich time, would shew always the time of the day at London or Greenwich: then the time of the day under any other meridian being found, the difference between that time and the London or Greenwich time corresponding to it, would give the difference of longitude.

90. That very excellent artist, Mr. John Harrison, after more than

thirty years close attention to this subject, has discovered many curious inventions to remove the irregularities to which all watch and clock-work were liable, that were constructed by the common methods. His inventions are so extraordinary, and seem so well adapted to remove the imperfections of clocks, that the commissioners for the longitude granted him some considerable gratuities to enable him to bring his notions to the desired perfection. Experiments of his watch were made in the latter end of the year 1761, and in the beginning of the year 1762, between Portsmouth and Jamaica; and although the result did not fully come up to the wishes of the public, yet it proved sufficient to induce the commissioners to enable Mr. Harrison to make a second trial, between Portsmouth and Barbadoes; which succeeded so well, that the commissioners of longitude ordered him the sum of 10,000 pounds, upon his disclosing the mechanism of his WATCH, to a number of proper persons appointed to receive his communications; which have since been published, and watches of a similar construction have been made by other artists, which have succeeded equally with that which had been made by the inventor himself. Mr. Harrison has even improved his former works; and it is probable, that such watches may hereafter become more common, and be afforded for less than 100l. or a fourth part of their present value.

But to whatever degree of perfection such a movement may be brought, yet as every mechanic instrument must be liable to be injured by various accidents, it is certainly to be wished, that astronomical methods could be also so far improved, that the marine artist might be enabled to find his longitude from time to time with sufficient exactness by celestial observations.

91. Various astronomical methods have been proposed for finding the longitude at sea, some of which will hereafter be mentioned.

These methods chiefly depend on having an Ephemeris or Almanac adapted to the meridian of some known place, suppose Greenwich, for which the Nautical Almanac is fitted; which Ephemeris shall contain the Sun's place, right ascension, declination, the times of the planets passing the meridian, as also the rising and setting, the times of the eclipses of the Sun and Moon, together with those of Jupiter's satellites; the distances of the Moon from the Sun and some zodiacal stars at certain times, for every day in the year; and, in general, the times when any other remarkable celestial appearances may be seen at the place for which the Ephemeris is calculated. Then, as these celestial appearances are seen nearly at the same instant of absolute time from all parts of the Earth where they are visible: by knowing the relative times of the day, when such appearances are seen in two distant places, the difference of those times is known, and consequently the difference of longitude between those places.

92. METHOD V. *By the Sun's declination.*

By some of the means shewn in Book V. between the Articles 185 and 204, or by any other means, let observations of the Sun be taken, from which his declination may be computed at those times.

Take the difference between this computed declination, and that for the noon of the same day at London, as shewn by the Ephemeris; from which take also the daily difference of declination at that time, and say,

As

between this time and the London time, converted into degrees, will shew the difference of longitude; and if the London time be less than the observed time, the diff. of longitude is east; otherwise it is west.

95. The beginning of these eclipses, called *immersions*, generally happen on the west side of Jupiter; and the endings, called *emergions*, to the eastward of the planet; and both happen at a very small distance from the planet, seldom exceeding its half diameter.

The best observations for finding the difference of longitude, are those made on the first satellite, or that which moves nearest to Jupiter; but it should be observed, that its emergions are not visible from the time of Jupiter's conjunction with the Sun, to the time of his opposition; and the immersions are not visible from the time of the planet's opposition to the Sun, to the time of its conjunction.

EXAM. Suppose by the Almanac for 1773, an immersion of Jupiter's first satellite is visible at London on October 23^d, at 13h. 23m. 15s. and I am, by my dead reckoning, in longitude 72 deg. to the west of London; I observed on the same day the immersion at 8h. 40m. 45s.: Required the difference of longitude.

The difference between 13h. 23m. 15s. and 8h. 40m. 45s. is 4h. 42m. 30s.

And 4h. 42m. 0s. is equal to $70^{\circ} 32'$ for the diff. of log. westward.

96. The eclipses of Jupiter's satellites may be well observed by one of Dollond's new achromatic telescopes, of three feet in length, or by a reflecting telescope of about 18 or 24 inches focal length. As these eclipses happen almost daily, they prove the most ready means of determining the longitudes of places at land, and by them the longitudes of sea-coasts may be better ascertained than they are at present; and whenever Jupiter is to be seen, they might be applied at sea, even oftener than they would be wanted, could they be observed with sufficient accuracy in a ship under sail.

97. METHOD VIII. *By eclipses of the Moon.*

This is performed much in the same manner as by the last method.

For if in two or more distant places, where an eclipse of the Moon is visible, the times of the beginning or ending are carefully observed, as also the times when any number of digits were eclipsed; or when the Earth's shadow begins to touch, or to leave any remarkable spot on the Moon's face; then will the difference of the times, when the observations of like kind were made, give the difference of longitude between the places of observation. But these eclipses happen too seldom to derive any general use from them.

98. METHOD IX. *By an occultation of a fixed star by the Moon.*

An occultation of a fixed star by the Moon is, when a star, lying in the line of the Moon's motion, is eclipsed by that planet.

The method of computing the difference of longitude between London, and a place where the time of the occultation is observed, is shewn in Halley's Astronomical Tables: and the method of delineating such an occultation is shewn in De la Caille's Elements of Astronomy.

But the method of finding the difference of longitude by an occultation, is rather too intricate and tedious to become of general use at sea.

99. The

99. The great Dr. Halley, and after him the Abbé de la Caille, and others, have reckoned the best astronomical method for finding the longitude at sea to be, when the distance of the Moon from the Sun, or from a Star is used : for the Moon's daily mean motion being about 13 degrees, her hourly mean motion is about half a degree, or 1 min. of a degree in two minutes of time ; and so an error of one minute of a degree in position will produce an error of two minutes in time, or half a degree in longitude. And if by observation it is determined what part of her daily motion the Moon has run through, during the interval between a certain point of time under a known meridian, and the instant of time when the observations are made on her under an unknown meridian, then her daily motion at that time will have to the part thereof, determined by observation, the same ratio which 24 hours have to the interval of time taken to describe that arc.

100. M. de la Caille, in the prosecution of his method, directs a number of observations to be made one after another, in which the interval of time is to be diligently noted : and observes, that many errors will be apt to arise here from the instrument, the observations, and the calculations, which must jointly affect the longitude deduced ; so that the most experienced artist ought not, in general, to expect on a single set of observations to find his longitude nearer than to two or three degrees of the truth. He therefore proposes, that each set of observations should be taken by two or more observers at the same time ; by which, from a mean taken between them, the longitude may probably be found within a degree and a half ; although it may happen, that by an extraordinary degree of diligence and skill, and by a lucky compensation of errors, a result within a degree of the truth may be obtained. But the Rev. Dr. Maskelyne, the Astronomer Royal, who has had great experience in this matter, recommends the set of observations to be divided among different persons, each observing at the same time his respective part, and the computations to be made, either from a good Ephemeris, or from the best Lunar tables, in which case the result may in general determine the longitude at sea within a degree of the truth.

101. Since Sir Isaac Newton's discovery of the true cause of the inequalities in the Moon's motion, which had from the earliest times perplexed astronomers, attempts have been made to form juster tables of her motion than before were possible to be effected ; and here the late professor Mayer of Gottengen has succeeded so well, and his tables come so near the truth in every part of the Moon's orbit, that they may be confided in for determining the longitude of a ship at sea, whenever the Moon is to be seen, within a degree at most ; which has been proved by a comparison of the Tables with the observations made at Greenwich observatory by the late Dr. Bradley, and by the present Astronomer Royal.

Preparatives for finding the longitude by an observed distance of the Moon from the Sun or a Star.

102. First. *To observe the angular distance between the Moon and any celestial object.*

I. *Between the Moon and the Sun.*

Turn down one of the screens, and hold the Hadley's quadrant so, that its plane shall pass through the Sun and Moon: look at the Moon through the transparent part of the horizon glass; and keeping her there, gently move the index till the Sun's image is brought into the silvered part of that glass: bring the nearest limbs of both objects into contact, and let the quadrant librate a little on the lunar ray, by which means the Sun will appear to rise and fall by the side of the Moon; and in this motion the nearest limbs are to be made to touch one another exactly by moving the index; when this is effected, the observation is completed, and the degrees cut by the Vernier's scale will shew their angular distance.

103.

II. *Between the Moon and a Star.*

If the Moon is very bright, turn down the lightest screen, and direct the plane of the quadrant through both objects: look at the star, as in a fore observation, through the clear part of the horizon glass: keep it there, and, by moving the index, bring the Moon's image into the silvered part of the same glass; let the quadrant gently librate about the star's ray, and the Moon will appear to rise and fall by the star; between the librations move the index till the Moon's enlightened limb is touched by the middle of the star, as by a tangent, and the observation is made.

R E M A R K S.

104. The enlightened limb of the Moon is always to be brought into contact with the Sun or star, even though the Moon's image is made to pass beyond the Sun or star, before the desired contact can be obtained.

Between the new and full Moons the enlightened limb is turned toward the west: and during the time from the full to the new Moon, the enlightened limb is turned to the east.

The observed distance of the nearest limbs of the objects, is to be increased by the sum of their semi-diameters; but when the contact is observed of their farthest limbs, by bringing one over the other, then the observed distance is to be lessened by the sum of their semi-diameters.

The stars have no apparent semi-diameters; but that of the Sun and Moon will be found in the Nautical Almanac for any given month and day.

105. When the face of the quadrant is held upward, the motion of the index forward brings the right-hand object, by reflection, into contact with the left-hand one seen directly; and when its face is held downward, the like motion of the index brings the left-hand object, by reflection, into contact with the right-hand one seen directly.

Therefore in north lat. the quadrant is to be used with its face upward, when the object to be seen by reflection is to the right-hand,

or

or westward of that seen directly. But when the object to be seen directly lies to the westward of that to be seen by reflection, the quadrant is to be used with its face downward.

106. A readiness in the use of the quadrant both ways, is to be obtained by practice only, which the learner may make familiar to himself by observing the position of land objects; and to attain an accuracy in observations let him select 6, 8, 10, or more objects lying around his view; and, beginning with any one of them, take the angular distance of the 1st and 2d, the 2d and 3d, the 3d and 4th, and so on all round, ending with the last and first; and the sum of all these angles should make 360 degrees.

In a Hadley's quadrant of 15 inches radius, if the limb and the Vernier's scale are well divided, the measure of an arc may be read to thirds or quarters of a minute, with the assistance of a magnifying glass.

107. Secondly. *To correct the apparent angular distance observed between the Moon and any other celestial object: or to reduce the distance, observed at the surface, to what it would appear if observed from the center of the earth.*

It was shewn in Book V. Art. 66, that the apparent place, in which the Moon is seen in the heavens from the surface of the earth, is generally not her true place on account of the parallax; so that her apparent place should be corrected, as well for the error of parallax as for that of refraction: the same may be observed of the Sun; but the parallax of the stars is too small to affect their places sensibly, and therefore the refraction only is to be applied to them. Because the apparent places of celestial objects want correction, their apparent distance does also stand in need of being corrected, especially where the Moon is concerned; how to do this is shewn in the following precepts.

1st. In the triangle formed by the observed distance of the objects and their zenith distances, find the angles at each object comprehended between the observed distance and respective vertical or azimuth circle.

(IV. 154)

2d. By the Almanac find the Moon's horizontal parallax at the time of observation, reduced to the meridian of the Almanac.

3d. Say, as radius is to the co-sine of the Moon's altitude;
So is the horizontal parallax to the parallax in altitude.

4th. Say, as radius is to the co-sine of the said angle at the Moon;
So is the diminished parallax to one error in distance.

Which is to be subtracted, if the angle at the Moon is acute; otherwise it is to be added.

5th. Also say, as rad. is to the cos. of the said angle at the Sun or star;
So is the refraction on its zenith distance to an error in dist.

Which is to be added, when the angle at the Sun or star is acute, otherwise this error is to be subtracted.

EXAM.

EXAM. I. Suppose on the 6th of August 1772, in a place 96 degrees to the west of London, at 5h. 36m. P. M. by a watch, the distance of the nearest limbs of the Sun and Moon should be observed to be $68^{\circ} 10' 24''$, at the time the altitude of the Sun's lower limb is $31^{\circ} 44' 12''$, and the altitude of the Moon's lower limb is $23^{\circ} 44' 12''$, the height of the eye above the water being allowed for: Required what would be the true distance of the centers of the Sun and Moon.

By the Almanac, the semi-diameters of the Sun and Moon at that time will be found to be each of $15' 48''$. Hence the apparent altitude of the Sun's center is 32° , of the Moon's center is 24° , and the apparent distance of the centers is $68^{\circ} 42'$.

Also 96° W. is 6h. 24m. to which 5h. 36m. being added, give 12h. P. M. at London; and the Moon's horizontal parallax at the given London time is $58' 39'' = 58,65$.

Given the Sun's zenith distance 58°
 the Moon's zenith distance 66
 the distance of their centers $68^{\circ} 42'$.

Required $\angle$ of position at the $\odot$.				Required the $\angle$ of position at the $\odot$.			
Working by Art. 154. B. IV.				Working by Art. 154. B. IV.			
$68^{\circ} 42'$	Ls, $68^{\circ} 42'$	0,03073		$68^{\circ} 42'$	Ls, $68^{\circ} 42'$	0,03073	
$66^{\circ} 0'$	Ls, $66^{\circ} 0'$	0,03927		$58^{\circ} 0'$	Ls, $58^{\circ} 0'$	0,07158	
$58^{\circ} 0'$	Ls, $30^{\circ} 21'$	9,70353		$60^{\circ} 0'$	Ls, $38^{\circ} 21'$	9,79272	
$2^{\circ} 42'$	Ls, $27^{\circ} 39'$	9,66658		$10^{\circ} 42'$	Ls, $27^{\circ} 39'$	9,66658	
$60^{\circ} 42'$	$30^{\circ} 21'$	19,44011		$70^{\circ} 42'$	$35^{\circ} 21'$	19,56161	
$55^{\circ} 18'$	$27^{\circ} 39'$	9,72005		$55^{\circ} 18'$	$27^{\circ} 39'$	9,78080	
	s, $31^{\circ} 39\frac{1}{2}'$				s, $37^{\circ} 8'$		
$\angle$ at the moon = $63^{\circ} 19'$				$\angle$ at the Sun = $74^{\circ} 16'$			

As Rad. 10,00000
 To s, $\odot$'s alt. 24° 9,96073
 So horizon. paral. $58^{\circ} 65'$ 1,76827
 To paral. in alt. $53,58$ 1,72900
 Deduct refraction $2,3$
 Error in alt. $51,28$

As Rad. 10,00000	As Rad. 10,60000
To s, $\angle$ at $\odot$ $63^{\circ} 19'$ 9,65230	To s, $\angle$ at $\odot$ $74^{\circ} 16'$ 9,43323
So error in alt. $51,28$ 1,70995	So error in refr. $1,8$ 0,25527
To error in dist. $23,03$ 1,36225	To error in dist. $0,488$ 1,68850
Which is subtractive.	Which is to be added.

Now $23,03 - 0,488 = 22,54 = 22^{\circ} 32'$ Subtractive.

Then $68^{\circ} 42' - 0^{\circ} 22' 32'' = 68^{\circ} 19' 28''$. Which is the true distance of the centers of the Sun and Moon at the time of observation, as would be seen at the Earth's center.

EXAM. II. Suppose in the year 1762, in latitude $32^{\circ} 12' N.$ and longitude $38^{\circ} 30' W.$ of Greenwich by account on May 9th, at 12h. 34m. 19s. the apparent distance of the star Spica Virginis from the Moon's center was observed to be $51^{\circ} 28' 35''$, and at the same time, the apparent altitude of Regulus was $24^{\circ} 48'$, and that of the Moon's center was $12^{\circ} 30'$: Required the true distance of the star from the Moon's center.

THE WORK.

$51^{\circ} 29'$	0,10656	$51^{\circ} 29'$	0,10656
$65 \quad 12$	0,04202	$77 \quad 30$	0,01042
$13 \quad 43$		$26 \quad 1$	
3		$65 \quad 12$	
$91 \quad 13 \mid 45^{\circ} 36\frac{1}{2}'$	9,85404	$91 \quad 13 \mid 45^{\circ} 36\frac{1}{2}'$	9,85404
$63 \quad 47 \mid 31 \quad 53\frac{1}{2}$	9,72289	$39 \quad 11 \mid 19 \quad 35\frac{1}{2}$	9,52545
	19,72551		19,49647
$46^{\circ} 48\frac{1}{2}'$	9,86275	$34^{\circ} 3\frac{1}{2}'$	9,74823
$s, 93 \quad 37 \quad 8,79990$	s	$s, 68 \quad 7 \quad 9,57138$	
$123'' \quad 2,08990$		$50', 72 \quad 1,70518$	
$7'', 76 \quad 0,88980$		$18' 54'' \quad 1,27656$	
		$0 \quad 7\frac{3}{4}$	
		$19 \quad 01\frac{3}{4}$	
		App. dist. $51 \quad 28 \quad 35$	
		True dist. $51 \quad 9 \quad 33$	

The precepts by which these examples are worked are derived from principles shewn in the Appendix; but the operations may be somewhat shortened, thus:

In a triangle with the three sides, viz. the two apparent zenith distances, and the apparent distance of the centers, find the difference of azimuth.

With this difference of azimuth, and the corrected zenith distances, find the true distance of the centers.

This work may be done very compendiously by the following precepts, from Book IV. Art. 253, 255.

108. A compendium for finding the true distance between the Moon and Sun, or Star, from their observed altitudes and distance.

PRECEPTS.

- 1st. To the Arith. Comp. of the log. sine of half the apparent distance, add the log. sine of half the diff. of the apparent altitudes; the sum is the log. sine of a first arc.
- 2d. To the log. sine of half the apparent distance, add the log. co-sine of the first arc, reject radius, and the sum is the log. sine of a second arc.
- 3d. Add together twice the log. sine of the second arc, and the Arith. Complements of the log. co-sines of the two apparent altitudes, their sum is the log. of a third arc.

4th.

4th. To the log. of the third arc, add the log. co-sines of the corrected altitudes, the sum is the log. of a fourth arc.

5th. From half the log. of the 4th arc, take the log. sine of half the diff. of the corrected altitudes, there remains the log. tangent of a 5th arc.

6th. From half the log. of the 4th arc, take the log. sine of the 5th arc, and there remains the log. sine of half the true distance.

These precepts being expressed in the following short way, may assist the memory, and render the operation more easy.

1st. $L, s, \frac{1}{2}$ ap. dist. + $L, s, \frac{1}{2}$ diff. ap. alts.	= $L, s,$ 1st. arc.
2d. $L, s, \frac{1}{2}$ ap. dist. + $L, s,$ 1st. arc	= $L, s,$ 2d. arc.
3d. $2L, s,$ 2d. arc + $L, s,$ one ap. alt. + $L, s,$ oth. ap. alt.	= $L,$ 3d. arc.
4th. $L,$ 3d. arc + $L, s,$ one cor. alt. + $L, s,$ oth. cor. alt.	= $L,$ 4th. arc.
5th. $\frac{1}{2}L,$ 4th arc - $L, s, \frac{1}{2}$ diff. cor. alts.	= $L, t,$ 5th. arc.
6th. $\frac{1}{2}L,$ 4th arc - $L, s,$ 5th arc	= $L, s, \frac{1}{2}$ cor. dist.

Applying these precepts to the preceding examples, the work will stand in the following order.

EXAM. I. (See page 298) Here are given the apparent altitudes of the centers, viz. of the Sun 32° ; of the Moon 24° ; and their apparent distance $68^{\circ} 42'$; and the Moon's horizontal parallax $58' 39''$: Required the true distance.

Dist. = $68^{\circ} 42'$; its $\frac{1}{2}$ = $34^{\circ} 21'$	Alt. $\odot$ = $32^{\circ} 0' 0''$	Alt. D = $24^{\circ} 0' 0''$
Ap. alt. $\odot$ = 32°	Refr. — = $1 31$	Refr. — = $2 7^*$
Ap. alt. D = 24	Cor. alt. $\odot$ = $31 58 29$	Alt. cor. = $23 57 53$
Diff. = $8; \frac{1}{2}$ diff. = 4°	Cor. alt. D = $24 51 32$	Paral. + = $53 39^{\dagger}$
	Diff. cor. alts. = $7 6 57$	Cor. alt. D = $24 51 32$
	$\frac{1}{2}$ Diff. cor. alts. = $3 33 28$	
$L, s, \frac{1}{2}$ dist. = $34 21$	$0,24853$	$9,75147$ $L, s, \frac{1}{2}$ dist.
$L, s, \frac{1}{2}$ diff. ap. alts. = $4 0$	$8,84358$	
$L, s,$ 1st. arc.	$9,09211$	$9,99666$ $L, s,$ 1st. arc.
		$9,74813$ $L, s,$ 2d. arc.
		$9,74813$ $L, s,$ 2d. arc.
		$0,07158$ $L, s,$ $\odot$ alt. 32°
		$0,03927$ $L, s,$ D alt. 24°
		$19,60711$ $L,$ 3d. arc.
		$9,92854$ $L, s,$ $\odot$ cor. alt. $31^{\circ} 58 \frac{1}{2}'$.
		$9,95778$ $L, s,$ D cor. alt. $24^{\circ} 51 \frac{1}{2}'$.
		$39,49343$ $L,$ 4th. arc.
$\frac{1}{2} L, s,$ 4th. arc.	$19,74671$	$19,74671$ $\frac{1}{2} L,$ 4th. arc.
		$8,70277$ $L, s, \frac{1}{2}$ diff. cor. alts. $3^{\circ} 33' 28''$
$L, s,$ 5th. arc.	$9,99733$	$10,95394$ $L, t,$ 5th. arc.
$L, s, \frac{1}{2}$ cor. dist. = $34^{\circ} 9' 44''$	$9,74938$	
True dist. = $68 19 28$		

* The refractions are taken from table, art. 55.

† The parallax is taken from table, art. 56.

But the parallax in alt. may readily be found by the Gunter's scale, thus: The extent, on the sines, from rad. to the co-sine of the alt.

Will reach on the numbers from the hor. par. to the paral. in alt.

EXAM.

EXAM. II. Given the observed distance of the Moon from the Sun 85° ; the Sun's alt. $5^{\circ} 0'$; the Moon's alt. $30^{\circ} 0'$; and her horizontal parallax $60' 0'$: Required the true distance.

Now rad. : $s, 30^{\circ} :: 60' : 51' 58'' = \text{par. in alt. by Gunter's Scale.}$

Dist. = $85^{\circ} 0'$; its $\frac{1}{2} = 42^{\circ} 30'$.

p 's alt. = $30^{\circ} 00'$

$\odot$'s alt. = $5 00$

Diff. = $25 00$

$\frac{1}{2}$ diff. = $12 30\frac{1}{2}$ ap. alts.

$L, s, 42 30$

$L, s, 12 30$

$L, s, 1 \text{ ft. arc}$

0,17032

0,33534

9,50566

$\odot$	$5^{\circ} 0' 0''$	D	$30^{\circ} 0' 0''$
	<u>9 54</u>		<u>1 38</u>
	4 50 06		29 58 22
	30 50 20		+ 51 58
	<u>26 0 14</u>		<u>30 50 20</u>

13 00 $7\frac{1}{2}$ diff. true alts.

9,82968 $L, s, 42 30$

9,97648 $L, s, 1 \text{ ft. arc}$

9,80616 $L, s, 2 \text{ d. arc.}$

9,80616 $L, s, 2 \text{ d. arc}$

0,06247 $L, s, 30^{\circ} 0'$

0,00166 $L, s, 5 0$

19,67645 $L, 3 \text{ d. arc}$

9,99845 $L, s, 4^{\circ} 50'$

9,93380 $L, s, 30 50$

39,60870 $L, 4 \text{ th. arc}$

$\frac{1}{2} L, 4 \text{ th. arc}$

19,80435

19,80435 $\frac{1}{2} L, 4 \text{ th. arc}$

9,35215 $L, s, 13^{\circ} 0'$

$L, s, 5 \text{ th. arc}$

9,97450

10,45220 $L, s, 5 \text{ th. arc.}$

$\frac{1}{2}$ Diff. $42^{\circ} 31' 15''$

9,82985

85 2 30 the true dist.

EXAM. III. Suppose the apparent dist. of the Moon and a Star was $51^{\circ} 28' 35''$; the Star's altitude $24^{\circ} 48'$; the Moon's altitude $12^{\circ} 30'$, and her horizontal parallax $56' 15''$: Required the true distance.

Dist. $51^{\circ} 28' 35''$; its $\frac{1}{2} = 25^{\circ} 44' 17\frac{1}{2}''$

Ap. alt. * $24^{\circ} 48'$

D $12 30$

Diff. = $12 18$

$\frac{1}{2}$ diff. = $0 09$ ap. alts.

$L, s, 25^{\circ} 44' 17''$

$L, s, 6 9$

$L, s, 1 \text{ ft. arc.}$

0,36226

9,02992

9,39218

* $24^{\circ} 48' 0''$ D $12^{\circ} 30' 0''$

2 3

24 45 57

13 20 48

11 25 9

5 42 34 $\frac{1}{2} = \frac{1}{2}$ diff. true alts.

9,63774 $L, s, 25^{\circ} 44' 17\frac{1}{2}''$

9,98636 $L, s, 1 \text{ ft. arc}$

9,62410 $L, s, 2 \text{ d. arc}$

9,62410 $L, s, 2 \text{ d. arc}$

0,04202 $L, s, 24^{\circ} 48'$

0,01042 $L, s, 12 30$

19,30064 $L, s, 3 \text{ d. arc}$

9,95810 $L, s, 24^{\circ} 46'$

9,98810 $L, s, 13 21$

39,24684 $L, 4 \text{ th. arc}$

19,62342 $\frac{1}{2} L, 4 \text{ th. arc}$

8,99775 $L, s, 5^{\circ} 42' 34''$

10,62507 $L, s, 5 \text{ th. arc}$

$\frac{1}{2} L, s, 4 \text{ th. arc.}$

19,62342

$L, s, 5 \text{ th. arc}$

9,98816

$\frac{1}{2}$ Diff. $25^{\circ} 34' 50''$

9,63526

Diff. $51 9 40$

EXAM.

EXAM. IV. Let the apparent distance of the Moon and a Star be $102^{\circ} 30'$; the Star's alt. $15^{\circ} 25'$; the Moon's alt. $27^{\circ} 30'$; and her hor. par. $57' 3''$: Required the true distance.

Dist. $102^{\circ} 30'$; its $\frac{1}{2} = 51^{\circ} 15'$.

Ap. alt. * $15^{\circ} 25'$

D $27^{\circ} 30'$

Diff. $12^{\circ} 5'$

$\frac{1}{2}$ diff. $6^{\circ} 2\frac{1}{2}'$ ap. alts.

L, s, $51^{\circ} 15'$

L, s, $6^{\circ} 2\frac{1}{2}'$

L, s, 1st. arc

0,10797

9,02223

9,13020

* $15^{\circ} 25' 0''$	D $27^{\circ} 30' 0''$
— 3 25 —	— 1 49 —
15 21 35	27 28 11
28 18 47	+ 50 36
12 57 12	28 18 47
6 28 36	= $\frac{1}{2}$ diff. true alts.

9,89203 L, s, $51^{\circ} 15'$

9,99601 L, s, 1st. arc

9,88804 L, s, 2d. arc

9,88804 L, s, 2d. arc

0,01591 L, s, $15^{\circ} 25'$

0,05207 L, s, $27^{\circ} 30'$

19,84406 L, 3d. arc

9,94466 L, s, $28^{\circ} 18\frac{3}{4}'$

9,98420 L, s, $15^{\circ} 21\frac{3}{4}'$

29,77292 L, 4th. arc

19,88646 $\frac{1}{2}$ L, 4th. arc

9,05223 L, s, $6^{\circ} 28\frac{3}{4}'$

10,83423 L, s, 5th. arc.

$\frac{1}{2}$ L, 4th. arc

L, s, 5th. arc

$\frac{1}{2}$ Dist. $51^{\circ} 5' 36''$

Dist. $102^{\circ} 11' 12''$

9,99539

9,89107

109. But of all the methods which have yet been thought of for reducing the apparent distance of the Moon from the Sun or a star to the true, the following one, derived from that invented by Mr. *Witchell*, late head master of the Royal Academy at Portsmouth, and printed in the Nautical Almanac for 1772, is perhaps best adapted to the disposition and capacities of seamen in general; as it is very short, requires the logarithms only to four places of figures besides the index, which may always be taken out at sight without making any proportions, and yet the result will be sufficiently exact.

PRECEPTS.

1st. From the Sun's refraction (55) take his parallax in altitude (V. 319.) and the remainder will be the correction of the Sun's altitude. The correction of a star's altitude is its refraction.

2d. Take the proportional logarithm of the Moon's horizontal parallax out of the Nautical Almanac, increase its index by 10, and subtract the log. co-sine of the D's apparent altitude from the sum: the remainder will be the proportional log. of her parallax in altitude; from which take the Moon's refraction (55), and there will remain the correction of her altitude.

3d. Add the Sun's apparent altitude to the Moon's, and take half the sum: subtract the less from the greater, and take half the difference. Add together the co-tangent of the half sum, the tangent of the half difference, and the co-tangent of half the observed distance: the sum, rejecting 20 from the index, is the log. tangent of an arc A.

4th. When the Sun's altitude is greater than the Moon's, take the difference between A and half the apparent distance; but if the Moon's altitude be greatest, take their sum; and to the co-tangent of this sum or difference, add the co-tangent of the Sun's apparent altitude, and the proportional

proportional log. of the correction of the sun's altitude; their sum, when 20 is rejected from the index, is the proportional log. of the first correction of the apparent distance.

5th. If the diff. of arch A, and half the apparent distance was taken in the preceding article, take now their sum; but if their sum was then taken, take now their difference, and to the log. co-tangent of this sum or difference, add the log. co-tangent of the moon's apparent altitude, and the proportional log. of the correction of the moon's altitude: the sum, rejecting 20 from the index, is the proportional log. of the second correction.

6th. If the arch A be less than half the apparent distance, the first correction must always be added to, and the second subtracted from, the apparent distance. But when the arch A is greater than half the apparent distance, both the first and second corrections must be added, if the sun's altitude be less than the moon's; but if the moon's be least, both must be subtracted, to give the corrected distance of the sun and moon.

7th. Add together the proportional log. of the sum and difference of the correction of the moon's altitude, and the second correction of the observed distance, the log. tangent of the corrected distance, and the constant log. 1,5820: the sum, rejecting 10 from the index, is the proportional logarithm of the third correction; to be added to the corrected distance when it is less than 90° , but subtracted when it is above, and this gives the true distance required.

EXAM. I. (See page 300 and 302.) *Given the apparent altitude of the Sun's center 32° , that of the Moon's center 24° , and the apparent distance of their centers $68^\circ 42'$, when the Moon's horizontal parallax was $58' 39''$: Required the true distance.*

The refr. on the sun's alt.	1' 31"	The D's hor. paral.	58' 39"	P. L.	10,4870
The sun's paral. in alt.	0 8	Moon's app. alt.	24° 00'	col.	9,9607
Correct. of the sun's alt.	1 23	Moon's par. in alt.	53' 35"	P. L.	0,263
Sun's app. alt.	32° 00'	Refraction	2 7		
Moon's app. alt.	24 00	Correct. D's alt.	51 28		
Sum	56 00	half is	28° 00'	co-tang.	10,2743
Difference	8 00	half is	4 00	tang.	8,8446
App. distance	68 42 00	half is	34 21	co-tang.	10,1653
First correction +	22½	Arc A	10 53	tang.	9,2842
Second correction	- 23 6	Diff.	23 28	co-tang.	10,3624
Corrected dist.	68 19 16½	Sun's alt.	32 00	co-tang.	10,2042
Third correction	+ 7½	Corr. ☉'s alt.	1' 23"	P. L.	2,1143
True distance	68 19 24	First correct.	0 22½	P. L.	2,6809
		Sum	45° 14'	co-tang.	9,9965
		Moon's alt.	24 00	co-tang.	10,3514
		Corr. D's alt.	51' 28"	P. L.	0,5437
		Second corr.	23 6	P. L.	0,8916
		Sum	1° 14' 34"	P. L.	0,3827
		Difference	28 22	P. L.	0,8024
		Corrected dist.	68° 19'	tang.	10,4005
		Constant logarithm			1,5820
		Third corr.	0' 7½	P. L.	3,1679

EXAM. II. (See 301 and 303.) Let the apparent distance of the Moon and a Star be $51^{\circ} 28' 35''$, the Star's altitude $24^{\circ} 48'$, the Moon's altitude $12^{\circ} 30'$, and her horizontal parallax $56' 15''$: What is their true distance?

The refract. on the *'s alt. is $2' 3''$		D's hor. paral.	$56' 15''$	P. L.	10,5051
		D's app. alt.	$12^{\circ} 30'$		9,9896
		D's par. in alt.	$54' 55''$	P. L.	0,5155
		D's refraction	$4' 12''$		
		Corr. D's alt.	$50' 43''$		
App. alt. D	$12^{\circ} 30'$	half is	$18^{\circ} 39' t$		10,4717
App. alt. *	$24' 48'$	half is	$6' 9' t$		9,0324
Sum	$37' 18'$	half is	$25' 44' t$		10,3170
Difference	$12' 18'$	Arch A	$33' 31' t$		9,8211
Observed dist.	$51' 28' 35''$	Difference	$7' 47' t$		10,8643
First correction	— 8	Star's alt.	$24' 48' t$		10,3353
2d correction	— 18 54	*'s refract.	$2' 3''$	P. L.	1,9435
Corrected dist.	$51' 9' 33''$	1st correction	$0' 8'$	P. L.	3,1431
3d correction	+ 15	Sum	$59^{\circ} 15' t$		9,7745
True distance	$51' 9' 48''$	D's alt.	$12' 30' t$		10,6542
		Corr. D's alt.	$50' 43''$	P. L.	0,5501
		2d correction	$18' 54'$	P. L.	0,9788
		Sum	$69' 37'$	P. L.	0,4126
		Difference	$31' 49'$	P. L.	0,7526
		Corrected dist.	$51^{\circ} 10' t$		10,0941
		Constant logarithm			1,5820
		3d correction	$0' 15''$	P. L.	2,8413

Note. The true distance, computed with the utmost exactness by spherical trigonometry, is $51^{\circ} 9' 54''$.

EXAM. III. Let the apparent distance of the Moon and Sun be $102^{\circ} 30'$, the Sun's alt. $15^{\circ} 25'$, the Moon's $27^{\circ} 30'$, and her horizontal parallax $57' 03''$: Required the true distance.

Refraction on the sun's alt.		$3' 25''$	D's hor. parall.	$57' 03''$	P. L.	10,4990
Parallax in alt. (V. 319)		8	D's app. alt.	$27^{\circ} 30' t$		9,9479
Correction of the sun's alt.		3 17	D's parall. in alt.	$50' 36''$	P. L.	0,5511
App. alt. D	$27^{\circ} 30'$		D's refraction	$1' 49''$		
App. alt. ☉	$15' 25'$		Correct. D's alt.	$48' 47'$		
Sum	$42' 55'$	The half is	$21^{\circ} 27' t$			10,4057
Difference	$12' 5'$	The half is	$6' 2' t$			9,0240
Observed dist.	$102' 30'$	The half is	$51' 15' t$			9,9045
First correction	+ 1 49	The arch A	$12' 11' t$			9,3342
2d correction	— 20 37	The sum	$63' 26' t$			9,6999
Corrected dist.	$102' 11' 12''$	The sun's alt.	$15' 25' t$			10,5595
3d correction	— 4	Correct. ☉'s alt.	$3' 17''$	P. L.		1,7389
True distance	$102' 11' 8''$	1st correction	$1' 49'$	P. L.		1,9974
		The difference	$39^{\circ} 4' t$			10,0906
		The D's alt.	$27' 30' t$			10,2835
		Correct. D's alt.	$48' 47''$	P. L.		0,5670
		2d correction	$20' 37'$	P. L.		0,9411
		Sum	$69' 24'$	P. L.		0,4139
		Difference	$28' 10'$	P. L.		0,8050
		Corrected dist.	$102^{\circ} 11' t$			10,6657
		Constant logarithm				1,5820
		3d correction	$0' 4''$	P. L.		3,4671

SECONDLY.

SECONDLY.

110. *To find the time at which two proposed celestial objects may be seen at a given distance; if observed from the center of the Earth under the meridian for which an Ephemeris is calculated.*

In the Nautical Almanac there are, ready computed, the distances of the enlightened limb of the moon from the sun, or from certain fixed stars every day, at the hours 3, 6, 9, 12, 15, 18, 21, and at noon.

Therefore seek in that Almanac amongst the computed distances of the proposed objects on the day given for the given distance, which if found there, the time is there also.

But if the given distance falls between two computed ones, A, B, (as it generally will) the corresponding time is to be found by proportional parts :

Saying, *As the difference of the computed distances A, B,
Is to the difference between A and the given distance;
So are three hours of time,
To the proportional time to be added to that of the distance A.*

EXAM. *At what time on the 21st of July, 1773, will the distance between the Virgin's spike and the Moon's enlightened limb, be equal to $54^{\circ} 56\frac{1}{4}'$, as seen from the center of the Earth under the meridian of Greenwich?*

On the 21st of July the given distance falls between the computed distances at 9h. and at midnight, viz. between $A = 55^{\circ} 31' 30''$, and $B = 53^{\circ} 51' 53''$; so that the time is between 9h. and 12h. P. M.

The difference between A and B is $1^{\circ} 39' 37'' = 5977''$, and the difference between A and $54^{\circ} 56\frac{1}{4}'$ is $0^{\circ} 35' 15'' = 2115''$.

Then $5977'' : 2115'' :: 3h. : 1h. 3m. 59s.$

And 9h. + 1h. 3m. 59s. = 10h. 3m. 59s. the time required.

111. *To find the longitude from observations made on the altitudes of the Moon and Sun, or Star, and of their distance.*

PRECEPTS.

- 1st. Let the watch be adjusted to true time, or its error found, a few hours before or after the time of observation. (58)
- 2^d. Let three persons, each having a good Hadley's quadrant, make observations; one taking the apparent angular distance of the moon from the sun or star; another taking the altitude of the moon; and the third, taking the altitude of the sun or star. These observations are to be made at one and the same time, which another person is to note by the watch. (44. 102)
- 3^d. Let the observed altitudes be corrected for the centers of the objects, and then the distance be corrected by parallax, &c. to have the true distance of the centers. (108. 109)
- 4th. Find the time at Greenwich, when this true distance happened. (110)
- 5th. The difference between the Greenwich time and the ship's time, is the difference of longitude.

REMARKS.

The best times of the day for taking the distance between the moon and sun, is from about half an hour after sun-rise to about ten o'clock in the forenoon; and in the afternoon nearly from two o'clock to half an hour of sun-set; because the apparent time may then be derived from the altitudes of the sun taken with the distance, in which case the watch is not necessary. If a watch be used, the altitudes for regulating it may be taken during any part of these intervals, and the distance, &c. at any time whatsoever, from half an hour after sun rising, to half an hour before it sets.

These observations may be taken during the four days preceding the moon's first quarter, and the four days following the last quarter; which make eight days in each lunation, or about a fourth part of the time between new moon and new moon, with a quadrant; but with a sextant for the four days preceding, and the four days following the quadratures also; that is, 15 or 16 days in each lunation.

The best time for making observations between the moon and star, is during the evening or morning twilight; or when the sea horizon can be seen distinct enough to take an altitude sufficiently accurate; and when the moon has between 5° and 15° of altitude, or not exceeding 20° ; although any altitude may be used with a distinct horizon.

Choose a known star to the eastward or westward of the moon, lying nearly in the line of the moon's path; that is, in a right line conceived to pass through the moon's center perpendicular to the right line joining her cusps, or horns: but between the full moon and her quadratures the direction of her shortest diameter points out her path.

The distance of the star from the meridian should be two hours at least, but a greater distance is better, if the apparent time be deduced from it; but if a watch be used, and the apparent time be deduced from other altitudes, this is not material; and the star's altitude should not be less than 5 degrees.

If two, three, or more sets of observations be made, as near to each other as possible, and the means of the times by the watch, of the distances, and of the respective altitudes, be taken, these means may be esteemed a set of observations more to be depended on than any single set: or the longitudes may be computed to each set, and the mean of the results be taken for the true longitude.

EXAM.

EXAM. I. Being by account in latitude 40° N. and longitude 28° W. of Greenwich, on the 24th of July, 1772; the watch being well regulated to apparent time, and the Hadley quadrants well adjusted, the distance between the nearest limbs of the Sun and Moon, and the altitudes of their lower limbs were observed as follows, the height of the eye being allowed for: Required the ship's true longitude.

Time 21h. 24m. Sun's alt. $48^{\circ} 41'$. Moon's alt. $8^{\circ} 10'$ Dist. $60^{\circ} 43\frac{1}{2}'$
 $\begin{array}{r} 21 \quad 26 \\ \hline \end{array}$ $\begin{array}{r} 48 \quad 59 \\ \hline \end{array}$ $\begin{array}{r} 8 \quad 40 \\ \hline \end{array}$ $\begin{array}{r} 60 \quad 44\frac{1}{2} \\ \hline \end{array}$
Means $\begin{array}{r} 21 \quad 25 \\ \hline \end{array}$ $\begin{array}{r} 48 \quad 50 \\ \hline \end{array}$ $\begin{array}{r} 8 \quad 25 \\ \hline \end{array}$ $\begin{array}{r} 60 \quad 44 \\ \hline \end{array}$

Now Sh. time 21h. 25m. P.M. + 1h. 52m. W. = 23h. 17m. P.M. at Greenw. (57)

At this time by almanac, the sun's $\frac{1}{2}$ diam. = $15' 48''$ } Sum $31' 02''$

Moon's $\frac{1}{2}$ diam. = $15' 14''$

Her hor. parallax = $55' 54''$

Then $60^{\circ} 44' + 31' 02'' = 61^{\circ} 15' 02''$ the apparent distance.

And $48^{\circ} 50' + 15' 48'' = 49^{\circ} 5' 48''$ the alt. of sun's center.

And $8^{\circ} 25' + 15' 14'' = 8^{\circ} 40' 14''$ the alt. of moon's center.

Also rad. : $5' 8'' \frac{2}{3} :: 55' 54'' : 55' 10''$ the par. in alt. by the Gunter.

Now dist. $61^{\circ} 15' 2''$; its $\frac{1}{2} = 30^{\circ} 37' 31''$

@ ap. alt. $49^{\circ} 5' 48''$

D ap. alt. $8^{\circ} 40' 14''$

Diff. $40^{\circ} 12' 34''$

$\frac{1}{2}$ Diff. $20^{\circ} 12' 47''$ of app. alts.

L, s, $30^{\circ} 37' 31''$ 0,29292

L, s, $20^{\circ} 12' 47''$ 9,53846

L, s, 1ft. arc 9,83138

@ alt. $49^{\circ} 5' 48''$ D alt. $8^{\circ} 40' 14''$

Ref. — 49 — 6 1

@ $49^{\circ} 4' 49''$ $8^{\circ} 34' 13''$

D $9^{\circ} 29' 23''$ Par. + $55' 10''$

Diff. $39^{\circ} 35' 36''$ $9^{\circ} 29' 23''$

$19^{\circ} 47' 48'' = \frac{1}{2}$ diff. true alts.

9,70708 L, s, $30^{\circ} 37' 31''$

9,86619 L, s, 1ft. arc

9,57327 L, s, 2d. arc

9,57327 L, s, 2d. arc

0,18389 L, s, $49^{\circ} 5' 48''$

0,00499 L, s, $8^{\circ} 40' 14''$

19,33542 L, 3d. arc

9,81621 L, s, $49^{\circ} 4' 59''$

9,99401 L, s, $9^{\circ} 29' 23''$

39,14564 L, 4th. arc

19,57282 $\frac{1}{2}$ L 4th. arc.

9,52979 L, s, $19^{\circ} 47' 48''$

10,04303 L, s, 5th.

$\frac{1}{2}$ L, s, 4th arc 19,57282

L, s, 5th arc 9,86993

$\frac{1}{2}$ Diff. $30^{\circ} 18'$ 9,70289

$60^{\circ} 36'$ the true distance.

Again, by the Nautical Almanac 1772.

The dist. at 21h. is $61^{\circ} 37' 35'' = A$. And $61^{\circ} 37' 35'' = A$.

24th. is $60^{\circ} 11' 37'' = B$. $60^{\circ} 36' 0''$ at ship. (109)

$1^{\circ} 25' 58'' = 85^{\circ} 58''$ $1^{\circ} 1' 35'' = 61^{\circ} 35''$

Now (I. 40) $85^{\circ} 58'' = 85,966$; and $61^{\circ} 35'' = 61,5833$.

Then (I. 46) As $85,96 : 61,583 : : 3h. : 2h. 8m. 56s.$ time above A.

Greenwich time

Ship's time

True diff. longitude

By account diff. long.

21 time A.

23 08 56

21 25 0

1 43 56

1 52

Error $8^{\circ} 4' = 2^{\circ} 1'$

A a 3

EXAM.

EXAM. II. Suppose in 1773, Nov. 6th, at 14h. 15m. 14f. apparent time; being by account in lat. $48^{\circ} 19' S$. long $116^{\circ} 15' E$. the observed distance between Aldebaran and the Moon's farthest limb should be $58^{\circ} 30' \frac{1}{4}$; the Star's alt. $25^{\circ} 10'$; the alt. of the Moon's lower limb $8^{\circ} 2' 50''$: Required the ship's true longitude.

Now Sh. time 14h. 15m. 14f. P.M. — 7h. 45m. E = 6h. 30m. 14f. at Greenw. (57)
At this time D's semi-diam. = $15' 10''$; and hor. parallax $55' 40''$ by Alman.

And $58^{\circ} 30' 15'' - 15' 10'' = 58^{\circ} 15' 5''$ the apparent distance.

And $8^{\circ} 2' 50'' + 15' 10'' = 8^{\circ} 18' 00''$ the ap. alt. of D's center.

Then dist. $58^{\circ} 15' 5''$; its $\frac{1}{2} = 29^{\circ} 7' 32''$

*'s alt. = $25^{\circ} 10'$

D's alt. = $8^{\circ} 18'$

Diff. = $16^{\circ} 52'$

$\frac{1}{2}$ diff. = $8^{\circ} 26'$

L's, $29^{\circ} 7' 32''$

L's, $8^{\circ} 26' 0''$

L's, first arc

0,31271

9,16631

9,47903

$\frac{1}{2}$ L, 4th. arc

19,66620

L's, 5th. arc

9,98123

$\frac{1}{2}$ Diff. $28^{\circ} 57' 22''$

9,68497

57 54 44 the true distance.

Now here is given the ship's time 14h. 15m. 14f. and the Corrected distance between the Moon's center and Aldebaran $57^{\circ} 54' 44''$. Required the ship's longitude.

By the Nautical Almanac: The diff. at 6h. is $57^{\circ} 38' 35'' A$ $57^{\circ} 38' 35'' A$. (109)

The diff. at 9h. $59^{\circ} 11' 43'' B$ $57^{\circ} 54' 44''$ Ship.

$1^{\circ} 33' 8'' (= 93' 8'') 16^{\circ} 9'$

Now (I. 40) $93' 8'' = 93,133'$; and $16^{\circ} 9' = 16,11'$.

Then (I. 46) As $93,133' : 16,15' : \odot$ 3h. : 9h. 31m. 13f. time above A,
6h. time A.

Greenwich time

6 31 13

Ship's time

14 15 14

True diff. longitude

7 44 1

Diff. long. by account

7 45

Error

$59' = 14 \frac{1}{4}'$ East.

EXAM.

EXAM. III. Suppose on the 13th of April 1772, on board a Ship in lat. 50° N. and long. 50° W. of Greenwich by account, with a watch and instruments well adjusted, the following observations were taken of the Star Pollux and the Moon's nearest limb, then to the east of the Star, the height of the eye being allowed for; Required the Ship's true longitude.

Time 9h. om. P. M; Alt. $\mathcal{D}$'s lower L. $16^{\circ} 45' 0''$; Alt. $\ast$ $54^{\circ} 50'$; dist. $45^{\circ} 12'$.

9 7	16 15 30	54 20	45 14
9 14	15 45 0	53 50	45 16
27 21	Sum 48 45 30	Sum 163 00	Sum 135 42

Mean 9 7 P. M. mean alt. $\mathcal{D}$ 16 15 10 $\ast$ 54 20 45 14

Now Sh. tim. 9h. 7m. P. M. + 3h. 20m. W. = 12h. 27m. P. M. Gr. tim. (57)

At this time by Alman. the $\mathcal{D}$'s semi-diam. = $16' 26''$
and horiz. parallax = $60' 18''$.

Then $45^{\circ} 14' + 16' 26'' = 45^{\circ} 30' 26''$ the apparent distance.

And $16' 15' 10'' + 16' 26'' = 16^{\circ} 31' 36''$ the alt. of the Moon's center.

Also rad. : $s' 16^{\circ} \frac{1}{4} :: 60' 18'' : 57' 15''$ the paral. in alt. by the Gunter.

Now dist. $45^{\circ} 30' 26''$; its $\frac{1}{2}$ is $22^{\circ} 45' 13''$

$\ast$'s ap. alt. $54^{\circ} 20' 0''$	Ref. — 41 — 3 11
$\mathcal{D}$'s ap. alt. 16 31 36	$\ast$ 54 19 19 16 28 25
Diff. 37 48 24	$\mathcal{D}$ 17 25 40 Par. + 57 15
$\frac{1}{2}$ Diff. 18 54 12 ap. alts.	Diff. 36 53 39 17 25 40
	18 26 50 = $\frac{1}{2}$ diff. true alts.

L, s, 22 45 13	0,41254
L, s, 18 54 12	9,51050
L, s, 1st. arc	9,92304

9,58746	L, s, $22^{\circ} 45' 13''$
9,73747	L, s, 1st. arc
9,32493	L, s, 2d arc
9,32493	L, s, 2d. arc
0,23428	L, s, $54^{\circ} 20'$
0,01832	L, s, $16^{\circ} 31' 36''$
18,90246	L, 3d. arc
9,76584	L, s, 54 19 19
9,97959	L, s, 17 25 40
38,64789	L, 4th. arc
19,32394 $\frac{1}{2}$	L, 4th. arc
9,50027	L, s, 18 26 50
9,82367	L, s, 5th. arc

$\frac{1}{2}$ L, 4th. arc 19,32394

L, s, 5th. arc 9,74390
 $\frac{1}{2}$ Dist, $22^{\circ} 20' 52''$ 9,58004

44 41 44 the true distance.

Again, by the Nautical Almanac 1772, April 13th.

The dist. at 12h. is $44^{\circ} 28' 30'' = A$ and $44^{\circ} 28' 30'' = A$.

at 15h. is $46' 13' 32'' = B$ 44 41 44 at Ship.

Diff. 1 45 2 = $105' 2''$ 0 13 14

Now (I. 40) $105' 02'' = 105,033$; and $13' 14'' = 13,233$

Then (I. 46) As $105,033 : 13,233 :: 3h. : oh. 22m. 40s.$ time above A.

12	time A.
12 22 40	Greenwich time.
9 7 0	Ship's time.

True diff. longitude 3 15 40
By acc. diff. long. 3 20 0

Error 4 20 = $1^{\circ} 5'$

A a 4

112. METHOD

112. METHOD XI. *To find the longitude at sea by an observation of the distance only.*

P R E C E P T S.

- 1st. Find the Greenwich time : to which, find (57)
 The right ascensions and declinations of the Sun and Star,
 The right ascension and declination of the Moon,
 And the horary angles between the meridians of the ship,
 Moon, and Sun or Star.
- 2d. With the Sun or Star's horary angle, the polar distance, and the ship's co-latitude, find the zenith distance. (IV. 253)
 With the Moon's horary angle, her polar distance, and the ship's co-latitude, find her zenith distance. (IV. 253)
- 3d. These true altitudes are to be altered by adding the refractions, and subtracting parallax (in the Moon's), to have the apparent altitudes.
- 4th. With the apparent altitudes, the true altitudes, and the observed distance, find the true distance. (108)
- 5th. To this distance find the Greenwich time. (109)
 Then the difference between this time and the ship time is the difference of longitude.

R E M A R K S.

The right ascension and declination of the stars are found for the year 1780, in Art. 312. Book V. : to which are to be applied the yearly variations, taken as many times as years since 1780.

The right ascensions and declinations for the Sun are found (in tables V. 309, 310, or) in the Nautical Almanac for the noon of each day ; and for the intermediate times by proportional parts. (V. 283, 284, 288).

The right ascensions and declinations of the Moon are given in the Nautical Almanac for every noon and midnight ; the parts for intermediate times may be found accurately enough by proportional parts.

The proportional parts for right ascensions and declinations are readily found, near enough, by the table, Art. 311. Book V.

The horary angles are found by the following precepts.

The ship time in degrees, added to the Sun's right ascension in degrees, gives the right ascension of the mid-heaven ; rejecting 360 degrees, when the sum is above that number.

The horary angle at the Sun is equal to the ship time.

The horary angle at a Star is equal to the difference between the Star's right ascension, and that of the mid-heaven.

The horary angle at the Moon is equal to the difference between the Moon's right ascension and that of the mid-heaven.

Note. The declination of an object, applied to 90 degrees, gives the polar distance of that object.

EXAM.

EXAM. I. 1772, November 15th, at 21h. P. M. suppose in a ship, in latitude 30° S. and longitude by account 7° E. of Greenwich, the distance of the nearest limbs of the Sun and Moon was observed to be $112^{\circ} 26' 10''$: What was the true longitude of that ship.

Ship's time, $21^h 0^m$ P. M. — $0^h 28^m$ E. = $20^h 32^m$ P. M. Greenwich time.
Nov. 15. $\odot$'s $\frac{1}{2}$ diam. = $16' 14''$; D 's $\frac{1}{2}$ diam. $15' 34''$; hor. parallax $57' 7''$.

For the Sun's right ascension.

Nov. 15. $\odot$'s r. a. = $15^h 25^m 22^{\frac{1}{2}}s$ diff. $4^m 8s$

16. $15^h 29^m 30^{\frac{1}{2}}s$

$24^h : 20^h 32^m :: 4^m 8s : 3^m 32s +$

$15^h 25^m 22s$

$\odot$'s right ascension

$15^h 28^m 54s$

Or $232^{\circ} 13' 30''$

For the Sun's declination.

$18^{\circ} 43' 37''$ diff. $14' 54''$

$18^{\circ} 58' 31''$

$24^h : 20^h 32^m :: 14' 54'' : 12' 43s +$

$18^{\circ} 43' 37''$

$\odot$'s declination

$18^{\circ} 56' 20''$ S.

For the D 's right ascension.

Nov. 15. mid. D 's r. a. $118^{\circ} 17'$ diff. $6^{\circ} 38'$

16. noon $124^{\circ} 55'$

$12 : 8 32 :: 6^{\circ} 38' : 4^{\circ} 43' +$

$118^{\circ} 17'$

D 's right asc. $123^{\circ} 0'$

For the D 's declination.

$15^{\circ} 41'$ diff. $1^{\circ} 15'$

$14^{\circ} 26'$

$12 : 8 32 :: 1^{\circ} 15' : 0^{\circ} 53'$

$15^{\circ} 41'$

D 's declination

$14^{\circ} 48'$ N.

Ship's time $315^{\circ} 0' = 21$ hours.

$\odot$'s right asc. $232^{\circ} 13' 30''$

$547^{\circ} 13' 30''$

360

Mid heav. $187^{\circ} 13' 30''$

D 's right asc. $123^{\circ} 0'$

D 's horar. ang. $64^{\circ} 13' 30''$

$\odot$'s horar. angle $45^{\circ} 0'$

For the Sun's altitude.

Given $\odot$'s $\angle = 45^{\circ}$; its $\frac{1}{2} = 22^{\circ} 30'$.

$\frac{1}{2} \angle \odot$ $22^{\circ} 30'$ 2, L, S, $\left\{ \begin{array}{l} 9,58284 \\ 9,58284 \end{array} \right.$

Pol. dif. $71^{\circ} 34' 0''$ L, S, $9,97583$

Co-lat. $60^{\circ} 0'$ L, S, $9,93753$

Diff. $11^{\circ} 34' 0''$ $39,07904$

$\frac{1}{2}$ diff. $5^{\circ} 31' 50''$ L, S, $19,53952$ $19,53952$

$8,98397$

$9,98380$ $10,55555$

$21^{\circ} 41' 4''$ $9,55572$

$42^{\circ} 8' 1'' = \odot$'s zen. distance.

$47^{\circ} 51' 1'' = \odot$'s true altitude.

For the Moon's altitude.

G. D 's $\angle = 64^{\circ} 13' 30''$; its $\frac{1}{2} = 32^{\circ} 6' 45''$

$\frac{1}{2} \angle \text{D}$ $32^{\circ} 6' 45''$ 2, L, S, $\left\{ \begin{array}{l} 9,72557 \\ 9,72557 \end{array} \right.$

Pol. dif. $104^{\circ} 48'$ L, S, $9,98535$

Co-lat. $60^{\circ} 0'$ L, S, $9,93753$

Diff. $44^{\circ} 48'$ $39,37402$

$\frac{1}{2}$ diff. $22^{\circ} 24'$ L, S, $19,68701$ $19,68701$

$9,58100$

$9,89609$ $10,10601$

$38^{\circ} 10' 00''$ $9,79092$

$76^{\circ} 20' = \text{D}$'s zenith distance.

$13^{\circ} 40' = \text{D}$'s true altitude.

To find the true distance of the centers of the Sun and Moon.

Now $112^{\circ} 26' 10'' + 16' 14'' + 15' 35'' = 112^{\circ} 57' 58'' =$ apparent distance.

Dist. $112^{\circ} 57' 58''$; its $\frac{1}{2} = 56^{\circ} 28' 59''$.

$\odot$'s alt. $37^{\circ} 30' 0''$ $\odot$'s alt. $14^{\circ} 31' 0''$

Ref. $+ 15$ $+ 32$

Ap. alt. $\odot$ $37^{\circ} 31' 15''$ $14^{\circ} 34' 32''$

Ap. alt. $\odot$ $13^{\circ} 39' 32''$ Par. $-55^{\circ} 0''$

$23^{\circ} 51' 43''$ $13^{\circ} 39' 32''$

$11^{\circ} 55' 52'' = \frac{1}{2}$ diff. app. alts.

$\odot$ true alt. $37^{\circ} 30'$

$\odot$ true alt. $14^{\circ} 31'$

$23^{\circ} 59'$

$\frac{1}{2}$ diff. true alts. $11^{\circ} 59' 30''$

L, s, $56^{\circ} 28' 59''$

L, s, $11^{\circ} 55' 52''$

L, s, 1st arc

0,07898

9,31541

9,39439

9,92102 L, s, $56^{\circ} 28' 59''$.

9,98621 L, s, 1st. arc.

9,90723

9,90723

0,10066

0,01246

19,92758

9,89947

9,98592

39,81296

19,90648

19,90648

9,31758

10,58890

9,92044

L, s, 2d. arc.

L, s, 2d. arc.

L, s, $37^{\circ} 31' 15''$

L, s, $13^{\circ} 39' 32''$

L, 3d. arc.

L, s, $37^{\circ} 30'$

L, s, $14^{\circ} 31'$

L, 4th arc.

$\frac{1}{2}$ L, 4th arc.

L, s, $11^{\circ} 59' 30''$

L, s, 5th arc.

$\frac{1}{2}$ L, 4th arc.

L, s, 5th arc.

$56^{\circ} 22'$

$112^{\circ} 44'$ the true distance of the Sun's and Moon's centers.

To find the Longitude.

Nov. 15. at 18^h dist.

21

$113^{\circ} 51' 27''$

$112^{\circ} 21' 8''$

$113^{\circ} 51' 27''$

$112^{\circ} 44' 0''$

$1^{\circ} 30' 19'' = 90' 19''$

$1^{\circ} 7' 27'' = 67' 27''$

Now (I. 40) $90' 19'' = 90,316'$; and $67' 27'' = 67,45$.

And (I. 46) $90,316 : 67,45 :: 3^h : 2^h 14' 38''$

18

Greenwich time for the true dist.

20 14 38

Ship's time for that distance

21

Difference of longitude in time

0 45 22

In degrees, &c,

11 20 30 E.

Diff. longitude by reckoning

7 0 0

Error in reckoning

4 20 30

EXAM.

EXAM. II. November 9, 1769, a Ship in latitude $24^{\circ} 15' N.$ longitude $47^{\circ} 14' W.$ of Greenwich: observed the distance of the Star *Aquila* to be $58^{\circ} 35\frac{1}{2}'$ from the Moon's nearest limb, at 6h. 31m. 4s. apparent time: Required the ship's true longitude.

Now 6h 31m 4s P. M. $+ 3^h 8^m 56^s W. = 9^h 40^m$ P. M. at Greenwich,

For the Sun's right ascension,

Nov. 9. $\odot$ R. A. $14^h 59^m 47^s$ diff. $= 4^m 3^s$
 10 15 3 50

Then $24 : 9 \ 40 :: 43 : 1 \ 38 +$

14 59 47

15 1 25 $= 225^{\circ} 21'$

For * *Aquila's* right ascension.

1764. * R. A. $19^h 39^m 16^s$
 5 years variat. $+ \quad 12$

1769. *'s R. A. $19 \ 39 \ 28 = 294^{\circ} 52'$

For D's right ascension.

Nov. 9. n. D's R. A. $348^{\circ} 16'$ diff. $= 6^{\circ} 15'$
 9. midn. 354 31

Now $12^h : 9^h \ 40 :: 6^{\circ} 15' : 5^{\circ} \ 2' +$

348 16

D's R. A.

353 18

Ship's-time

$97^{\circ} 46' = 6^h \ 31^m \ 4^s$

Sun's right ascension

225 21

R. A. mid. heaven

323 7

Star's R. A.

294 52

* west of sh. meridian

28 15

To find the Star's altitude.

Given h. $\angle 28^{\circ} 15'$

Half $= 14^{\circ} \ 7\frac{1}{2}'$ 2L, $\left\{ \begin{array}{l} 9,38746 \\ 9,38746 \end{array} \right.$

*'s P. D. $81^{\circ} 43' 37''$ L, $\left\{ \begin{array}{l} 9,99546 \\ 9,99546 \end{array} \right.$

Co-lat. $65 \ 45$ L, $\left\{ \begin{array}{l} 9,95288 \\ 9,95288 \end{array} \right.$

Diff. $15 \ 58 \ 37$ 38,73026

$\frac{1}{2}$ Diff. $19,36513$ 19,36513

$\frac{1}{4}$ Diff. $7 \ 59\frac{1}{4}$ L, $\left\{ \begin{array}{l} 9,14292 \\ 9,14292 \end{array} \right.$

... 9,93333 10,22221

15 41 9,43180

Zen. dist. $31 \ 22$, and $58 \ 38 =$ *'s alt.

For * *Aquila's* right declination.

1764. *'s declination $8^{\circ} 15' 41''$

5 years variation $+ \quad 42$

1769. *'s declination $8 \ 16 \ 23 N.$

For D's declination.

Nov. 9. n. D's decl. $0^{\circ} 38' N.$ diff. $2^{\circ} 36'$

9. midn. 3 14

$12^h : 9^h \ 40 :: 2^{\circ} 36' : 2^{\circ} \ 6' +$

0 38

D's declination

2 44 N.

323 7

353 18 D's R. A.

30 11 D's east of meridian.

To find the Moon's altitude.

Given h. $\angle 30^{\circ} 11'$

$\frac{1}{2}$ pol. $\angle = 15^{\circ} \ 5\frac{1}{2}'$ 2L, $\left\{ \begin{array}{l} 9,41558 \\ 9,41558 \end{array} \right.$

D's P. D. $87^{\circ} 22'$ L, $\left\{ \begin{array}{l} 9,99951 \\ 9,99951 \end{array} \right.$

Co-lat. $65 \ 45$ L, $\left\{ \begin{array}{l} 9,95988 \\ 9,95988 \end{array} \right.$

Diff. $21 \ 31$ 38,79055

$\frac{1}{2}$ Diff. $10 \ 45\frac{1}{2}$ L, $\left\{ \begin{array}{l} 19,39527 \\ 19,39527 \end{array} \right.$

$\frac{1}{4}$ Diff. $10 \ 45\frac{1}{2}$ L, $\left\{ \begin{array}{l} 9,27106 \\ 9,27106 \end{array} \right.$

9,90282 10,12421

18 6\frac{1}{2} 9,49245

$36 \ 13$, and $53 \ 47 =$ D's tr. alt.

To find the true distance between Aquila and D's center.

Nov. 9, 1769. D $\frac{1}{2}$ diam. = 15' 52". Dist. of centers 58° 51' 37".
Hor. paral. 58' 12". Then rad. : s, 53° 3' :: 58' 12" : 34' 30", by Gunter.

Dist. 58° 51' 37"; its $\frac{1}{2}$ 29° 25' 48"

☉'s alt. 58 38

D's alt. 53 38

Diff. 5 0

$\frac{1}{2}$ diff. 2 30 of the true alts.

L, s, 29° 25' 48"

L, s, 2 47 12

L, s, 1st arc.

0,30860

8,68679

8,99539

*'s alt. 58° 38' 0"

D's 53° 38' 0"

Refr. + 0 35

+ 0 42

* 58 38 35

53 38 42

D 53 4 12

34 30

5 34 23

53 4 12

$\frac{1}{2}$ diff. 2 47 12 app. alts.

9,69140 L, s, 29° 25' 48".

9,99786

9,68926

L, s, 2d. arc.

9,68926

L, s, 2d. arc.

0,28370

L, s, 58 38 35

0,22125

L, s, 53 4 12

19,88347

L, 3d. arc.

9,71643

L, s, 58 38

9,77302

L, s, 53 38

39,37292

L, 4th arc.

$\frac{1}{2}$ L, 4th arc

19,68646

19,68646

$\frac{1}{2}$ L, 4th arc

8,63938

L, s, 2 30

L, s, 5th arc.

9,99825

11,04708

L, s, 5th arc.

29 11 40

9,68821

58 23 20 the true dist. of * from D's center.

To find the Longitude.

Nov. 9. at 9^h P. M. * à D 58 1 37
12^h 59 29 51

58 1 37

58 23 20

1 28 14 = 88' 14"

21 43

Now, (I. 40) 1 28 14 = 88,23; and 21' 43" = 21,716.

And, (I. 46) 88,23 : 21,716 :: 3^h : 0^h 43^m 32^s

9

Apparent time at Greenwich
Ship

9 43 32

6 31 4

Difference of times

Longitude by account

3 12 28

3 8 56

28 = 48° 7' diff. longitude,

Error 3 32 = 0° 53'

S E C.

S E C T I O N XI.

Of a Ship's reckoning.

113. A SHIP'S RECKONING is that account, by which it can be known at any time where the ship is, and on what course or courses she must steer to gain her port.

114. DEAD RECKONING is that account deduced from the occurrences, which are written on the log-board.

The LOG BOARD is a large square board, or pannel of wainscot, painted black, on which is written in chalk whatever is thought worthy of notice from day to day; and for a proper disposition of such notes, the board is usually divided into five columns. The column on the left hand contains the 24 hours from the noon of one day to the noon of the next; in the second and third columns are the knots and fathoms the ship is found to run per hour, set against the hours when the log was hove; the fourth column contains the courses the ship steers; and in the fifth, or right-hand column, is written the winds, the alteration of the sails, the business doing aboard, and what other remarks the officer of the watch thinks proper to insert. For it should be observed, that it is usual to divide a ship's company into two parts, called the starboard and larboard watches, who do the duty of the ship for four hours and four hours alternately.

The LOG BOOK is a book ruled like the log-board, in order to contain the daily copies of the remarks written on the log-board, which is the only authentic record of the ship's transactions; and these are, by the persons who keep *Journals*, transcribed every day at noon into their log-books, from which they make the necessary deductions relative to the ship's place.

115. A SEA JOURNAL is a book, in which is truly entered the most remarkable daily occurrences relating to the ship during her voyage outward and homeward.

There are various ways of keeping sea journals, according to the different notions of mariners concerning the articles proper to be entered.

Some writers direct to keep such a kind of journal, as contains only an abstract of each day's transactions, specifying the weather, what ships or lands were seen, accidents on board, the latitude, longitude, meridional distance, course, and run. These particulars are to be drawn from the ship's log-book, or that kept by the person himself; for most good mariners keep private log-books.

Other authors recommend the keeping but one account, including the log-book and all the work of each day, with the deductions drawn from it. This method is adopted in this treatise, because it represents to the beginner the whole of each day's work: but when he is well versed in this method, he may abridge what part of it he pleases. But it is conceived, that a journal neatly kept, with all the particulars of the work commodiously ranged, will give more satisfaction to those who may afterwards have occasion to inspect it, than a journal containing the heads only, with all the intermediate parts suppressed.

The method here made choice of, to introduce the young mariner into this capital part of navigation, is, by shewing him first how to work a few
separate

separate days works independent one of another, and then to proceed to a continued journal of several successive days works; for the doing of which it was judged necessary to premise the following observations.

116. I. Mariners reckon time in the astronomical manner, beginning at noon, and counting from thence 24 hours to the next noon. The first 12 hours, from noon to midnight, they mark with P. M. signifying after mid-day; and the second 12 hours, from mid-night to noon, they mark with A. M. signifying after mid-night; and end their day's work on the noon of the nominal day. Hence their ship account is 12 hours earlier than the civil account of time; and consequently the Sun's declination, and other daily astronomical matters *fitted for noon*, must be sought for on the day according to their account of time: but if they are wanted for any other time of the day, they must be taken out for the day which precedes the given nautical day, which they are wanted for.

Thus that day's account which is marked Sunday the 9th of October, began on Saturday noon, and ends on Sunday noon.

II. If there is an observation for an amplitude or an azimuth, let that amplitude or azimuth be worked as is shewn between Article 22, and 28; and then find the variation as is shewn at Article 29; taking care, in these operations, that the declination for the proper day, time, and longitude, be used as shewn above, and in Book V. article 286.

III. Correct each course by the variation thus found, as at Article 30; also correct these corrected courses by the proper allowance for leeway, as is shewn at Articles 31, 32.

IV. Write these corrected courses in a Traverse Table, sum up the knots and fathoms, allowing eight fathoms to a knot, belonging to those hours in which the ship kept on the same course, and write the several sums as distances in the Traverse Table, against their respective courses.

V. Complete the Traverse Table as shewn in Book VII. 36, find the present latitude and longitude as shewn in Article 72, 73, 74, Book VIII. and the following examples, and then will the ship's place be obtained by dead reckoning.

VI. The present longitude each day may be found either by middle latitude or by Mercator's sailing; the one being preferable, when sailing nearly on a parallel of latitude, and the other when sailing near the meridian. In what follows, Mercator's sailing is used, when the course is less than five points, and middle latitude sailing when it is above.

VII. As the greatest trouble in using the Traverse Table, is to find a corresponding difference of latitude and departure, or meridional difference of latitude and difference of longitude, nearly equal to two given numbers, it has been judged proper to annex the two first figures of the natural tangent of the course, to the degrees at the top and bottom of the Traverse Table (VII. 67.); by which means the course may be found with greater facility from the diff. of lat. and departure, or from the merid. diff. of lat. and the diff. of long. Thus: Add cyphers to the depart. or to the diff. of long. and divide by the diff. of lat. or by the merid. diff. of lat.; look for the two first figures of the quotient amongst the numbers annexed to the degrees at the top or bottom of the Traverse Table, and the degree where it is found is the course or bearing sought. Let 672 merid. diff. of lat. and 353 diff. of long. be given to find the courses. 353, with cyphers annexed, being divided by 672 gives .53 in the quotient, which is found annexed to 28°, the course required.

117. EXAM. I. *August 25th, 1792, Yesterday noon we were in the latitude of $46^{\circ} 28'$ N. longitude $22^{\circ} 18'$ W. and have sailed till this day noon as by the log-board, the tide having all the time set S. b. E. $2\frac{1}{2}$ miles an hour: Required the ship's place, and the direct course and distance made good.*

LOG-BOARD.

TRAVERSE TABLE.

H.	K.	F.	Courses.	W inds.
1	6	3	NNE.	Wett.
2	6	2		
3	6	0		
4	6	4		
5	6	0		
6	6	1	ENE.	NW.
7	6	6		
8	5	2		
9	5	6		
10	5	4		
11	5	5		
12	5	3	E. b. S.	North.
1	5	7		
2	6	2		
3	6	0		
4	6	3		
5	6	4		
6	7	0	SSE.	
7	6	5		
8	7	3		
9	7	5		
10	7	1		
11	7	7		
12	7	3		

Courses.	Dif.	N.	S.	E.	W.
NNE.	31	28,6		11,9	
ENE.	35	13,4		32,3	
E. b. S.	36		7,0	35,3	
SSE.	51		47,1	19,5	
S. b. E.	60		58,8	11,7	
		42,0	112,9	110,7	Dep.
			42,0		
		D. lat.	70,9		

Depart. lat. = 46° 28' N. M. P. = 3156
Diff. lat. = 1 11 S.

Pres. lat. = 45 17 N. M. P. = 3054

Sum lats. = 91 45 M. D. lat. = 102

Middle lat. = 45 52

Co-middle lat. = 44 08

Dep. longitude = 22 18 W.

Difference long. = 2 39 E. Or 2° 40'.

Present long. = 19 39 W.

Direct course = S. 57° 15' E.

Distance = 131 miles.

Depart. lat. = $46^{\circ} 28'$ N. M. P. = 3156

Diff. lat. = 1 11 S.

Pres. lat. = $45^{\circ} 17'$ N. M. P. = 3054

Sum lats. = 91 45 M. D. lat. = 102

Middle lat. = 45 52

Co-middle lat. = 44 08

Dep. longitude = $22^{\circ} 18'$ W.

Difference long. = $2^{\circ} 39'$ E. Or $2^{\circ} 40'$.

Present long. = $19^{\circ} 39'$ W.

Direct course = S. $57^{\circ} 15'$ E.

Distance = 131 miles.

The courses and winds in the log-board being examined, it appears that the ship goes large, and has no leeway; therefore the several courses from the log-board are entered on the Traverse Table without alteration.

Next, the fathoms and knots belonging to each course are summed up, and the results are put in the column of distances in the Traverse Table; and to these courses and distances the whole difference of latitude and departure is found. (VII. 36)

Then the present lat. is found by VI. 51; the co-mid. lat. by VIII. 45; the present long. by VIII. 64; and the course and distance by VII. 33.

Or by Mercator's having found the present lat. find the meridional diff. lat. = 102 by VIII. 52; and the course and distance by VII. 33.

Then the diff. long. being found by VIII. 65, will be $2^{\circ} 40'$, differing by one mile from that found by middle latitude.

118. EXAM.

118. EXAM. II. *June 27, 1771, Being yesterday noon in latitude $25^{\circ} 30'$ S. and longitude $10^{\circ} 15'$ E. we have sailed till this day noon, as per log-board, in a current setting S. $2\frac{1}{2}$ miles an hour, the variation $1\frac{1}{2}$ point west: Required the ship's place.*

LOG-BOARD.				
H.	K.	F.	Courses.	Winds.
1	6	0	S. W.	WNW.
2	6	2		
3	6	4		
4	6	0		
5	5	3		
6	6	0	S. b. W.	W. b. S.
7	5	1		
8	5	4		
9	5	2		
10	5	3		
11	5	0		
12	5	2	SSW.	West.
1	5	2		
2	5	0		
3	4	6		
4	5	0		
5	5	1		
6	5	2	SE. b. S.	SW. b. S.
7	5	4		
8	5	4		
9	6	0		
10	6	0		
11	5	4		
12	5	5		

TRAVERSE TABLE.					
Courses.	Dif.	N.	S.	E.	W.
S. b. W. $\frac{1}{2}$ W.	30		28.7		8.7
S. b. E. $\frac{1}{2}$ E.	32		30.6	9.3	
S. $\frac{1}{2}$ E.	30		29.9	2.9	
SE. b. E. $\frac{1}{2}$ E.	39		18.4	34.4	
S. b. E. $\frac{1}{2}$ E.	60		57.4	17.4	
		D. lat.	165.0	64.0	8.7
				8.7	
				55.3	Dep.

Diff. lat. = $2^{\circ} 45'$ S.

Dep. lat. = $25^{\circ} 30'$ S. Merid. pts. 1583

Present lat. = $28^{\circ} 15'$ S. Merid. pts. 1768

Sum of lats. = $53^{\circ} 45'$ M. diff. lat. 185

Mid. lat. = $26^{\circ} 52'$

Co-mid. lat. = $63^{\circ} 08'$

Dep. long. = $10^{\circ} 15'$ E.

Diff. long. = $1^{\circ} 02'$ E. Or, $1^{\circ} 1\frac{1}{2}'$ E.

Present long. = $11^{\circ} 17'$ E.

Course is S. $18^{\circ} 30'$ E.

Distance is 174 miles.

The courses and winds in the log-board being examined, it appears that the ship is close hauled on each tack, and one point leeway being allowed (32) reduces the courses to SW. b. S., S. b. W., SE., SSE., and take a course for the current S.: these several courses being corrected by Art. 30, for the variation $1\frac{1}{2}$ point west, give those in the Traverse Table; to which the whole difference of latitude and departure is to be found as before.

And hence the present latitude and longitude may be found either by middle latitude, or Mercator's sailing; for as the ship is so near the equator, the difference will be almost insensible.

If a greater accuracy is required, which is very rarely wanted, especially in such small latitudes, the diff. of long. may be found to each course, as shewn in Book VIII. 77, 78, and thence the whole diff. long may be collected; but there will be no material difference found by such operation.

119. EXAM.

119. EXAM. III. Yesterday noon we were in lat. $33^{\circ} 40' N.$, long. $16^{\circ} 20' W.$, the sun was observed to set $50^{\circ} 18'$ from the north point of the compass; we have sailed till this day noon, as per log-board, in a current setting WSW. $1\frac{1}{2}$ mile an hour: Required the ship's place, and her course and distance to the west end of the Island of Madeira, June 4th, 1772.

LOG-BOARD.					TRAVERSE TABLE.					
H.	K.	F.	Courses.	Winds.	Courses.	Dif.	N.	S.	E.	W.
1	6	2	S. b. W.	West.	S. $1^{\circ} E.$	40		40,0	0,7	
2	6	0			S. $19^{\circ} W.$	179		68,9		12,2
3	6	3			S. $44^{\circ} W.$	58		41,7		40,3
4	7	0			S. $55^{\circ} W.$	36		20,6		29,5
5	7	2					D. lat.	171,2	0,7	82,0
6	7	3								0,7
7	7	2	SW. b. S.	W. b. N.					Dep.	81,3
8	7	2								
9	7	4								
10	7	6								
11	7	4								
12	8	1								
1	8	0								
2	8	5								
3	8	2								
4	7	5	SW. b. W.	NW.						
5	7	3								
6	6	3								
7	6	2								
8	6	0								
9	6	2								
10	6	1								
11	6	0								
12	6	1								

Before the courses can be corrected to put in the Traverse Table, the variation of the compass must be found from the Sun's true amplitude; which may be done by article 22, or by working the proportion in article 23, either by logarithms or the Gunter.

June 4th, 1772, the declination is $22^{\circ} 32' N.$
 As cos. $33^{\circ} 40'$: rad. :: sin. $22^{\circ} 32'$: sin. $27^{\circ} 22'$
 So that the true amplitude = $62^{\circ} 38' W.$
 Mag. amplitude = $50^{\circ} 18'$

(29) Variation = $12^{\circ} 20'$

The courses in the log-board being corrected by this variation and the lee-way in the 2d. course, will give the courses fitted for the Traverse Table.

M. P.

Madeira's lat. = $32^{\circ} 25' N.$ 2058
 Present latitude = $30^{\circ} 49' N.$ 1945
 Diff. latitude = $1^{\circ} 36'$ 113

Sum of latitudes = $63^{\circ} 14'$

Middle latitude = $31^{\circ} 37'$

Co-mid. latitude = $38^{\circ} 23'$

Madeira's long. = $17^{\circ} 21' W.$

Present long. = $17^{\circ} 56' W.$

Diff. longitude = $0^{\circ} 35' E.$

The course (57) = $N. 17^{\circ} 15' E.$

The distance = 101 miles.

Depart. latitude = $33^{\circ} 40' N.$

Diff. latitude = $2^{\circ} 51' S.$

Present latitude = $30^{\circ} 49' N.$

Sum of latitudes = $64^{\circ} 29'$

Middle latitude = $32^{\circ} 14'$

Co-middle latitude = $57^{\circ} 46'$

Depart. longitude = $16^{\circ} 20' W.$

Diff. longitude = $1^{\circ} 36' W.$

Present longitude = $17^{\circ} 56' W.$

In the work for the amplitude the lat. at Sun-set was taken the same as at noon; for although there were about 46m. of southing in that time, and so the lat. at Sun-set was about $32^{\circ} 54'$, yet the amplitude being only about 15 less, the alteration in variation would scarcely affect the diff. lat. and dep. found from the courses so corrected.

120. EXAM. IV. Being yesterday noon in lat. $19^{\circ} 30' S.$; long. $0^{\circ} 10' E.$; this forenoon we observed the Sun's altitude to be $10^{\circ} 40'$, when he was $80^{\circ} 30'$ from the north point of the compass, and his declination $17^{\circ} 27' N.$; we have sailed till this day noon, as per log-board, in a current setting by the compass WNW. $\frac{1}{2}$ mile an hour: Required the ship's place, with her direct course and distance to the Island of St. Helena.

LOG-BOARD.				
H.	K.	F.	Courses.	Winds.
1	6	7	N. b. E.	E. b N.
2	6	2		
3	6	4		
4	6	3		
5	6	1		
6	6	0		
7	5	4	North.	E. N. E.
8	5	4		
9	5	0		
10	5	3		
11	5	6		
12	5	0		
1	5	7		
2	6	4	NNW.	NE.
3	6	4		
4	7	0		
5	7	3		
6	7	4		
7	7	5		
8	7	0		
9	7	2		
10	7	0		
11	6	3		
12	6	0		

TRAVERSE TABLE.					
Courses.	Dist.	N.	S.	E.	W.
N. $13^{\circ} 30' W.$	38	36.9			8.9
N. $24^{\circ} 45' W.$	38	34.5			15.9
N. $47^{\circ} 15' W.$	76	51.7			55.6
N. $81^{\circ} 00' W.$	12	1.9			11.8
		125.0			92.2
		D. lat.			Dep.

Before the courses can be corrected, an azimuth must be worked as in articles 26 and 27.

Decl.	$90^{\circ} 00'$ 17 27	Lat.	$90^{\circ} 00'$ 19 30	Alt.	$90^{\circ} 00'$ 10 40
A =	107 27	Co-lat.	70 30	Co-alt.	79 20
D =	8 50			Co-lat.	70 30
Sum	116 17	$58^{\circ} 08' = \frac{1}{2}$ sum.		D =	8 50
Diff.	98 37	$49^{\circ} 19' = \frac{1}{2}$ diff.			

Then by the Gunter, the extent from $58^{\circ} 8'$ to $79^{\circ} 20'$ on the fines, will reach from $70^{\circ} 30'$ to some point beyond 90° ; rest one foot there, and extend the other to $49^{\circ} 19'$; this extent will reach from the beginning of the versed fines to the versed fine of 67° , the azimuth from the south. Hence the variation will be $13^{\circ} 30' W.$; with which the courses in the log-board are to be corrected; as well as for the lee-way; the ship being close hauled.

For the bearing and dist. of St. Helena.

St. Helena's lat.	$= 16^{\circ} 00' S.$	M. P.	973
Present latitude	$= 17^{\circ} 25' S.$		1061
Diff. latitude	$= 1^{\circ} 25'$		88
Sum latitudes	$= 33^{\circ} 25'$		
Middle latitude	$= 16^{\circ} 42'$		
Co. mid. lat.	$= 73^{\circ} 18'$		
St. Helena's long.	$= 5^{\circ} 53' W.$		
Present long.	$= 1^{\circ} 26' W.$		
Diff. long.	$= 4^{\circ} 27' = 267 m.$		
Course N.	$71^{\circ} 30' W.$	(57)	
Distance	270 miles.		

For the ship's place.

Depart. latitude	$= 19^{\circ} 30' S.$
Difference of latitude	$= 2^{\circ} 05' S.$
Present latitude	$= 17^{\circ} 25' S.$
Sum of latitudes	$= 36^{\circ} 55'$
Middle latitude	$= 18^{\circ} 27'$
Co-middle latitude	$= 71^{\circ} 33'$
Depart longitude	$= 0^{\circ} 10' E.$
Diff. longitude	$= 1^{\circ} 36' W.$
Present longitude	$= 1^{\circ} 26' W.$

Here the azimuth is worked with yesterday's lat.; if it had been worked with this day's latitude the variation would have been $12^{\circ} 30'$.

In

In the following Journal almost all the circumstances which can possibly attend a day's work, in any common voyage, are introduced. The ship is taken from the River *Thames*, conducted through the *Downs*, down the *English Channel*, and from thence over the Ocean, until she comes in sight of her port; namely, *Funchal* in the island of *Madeira*. In this navigation care has been taken to point out the usual business that occurs in the like circumstances of wind, weather, &c. The courses and distances run down the channel are such, as produce the bearings and distances of the places mentioned; and vessels frequently keep a track not very different from that which is here assumed. The astronomical observations are adapted to the times and places where they are put down; and it is apprehended, that the whole is conducted in such a manner, as might possibly have happened.

It is usual, in Journals, to mark the days of the week with the characters of the planets.

Thus ☉	stands for	Sunday.
☾		Monday.
♂		Tuesday.
♂		Wednesday.
♂		Thursday.
♀		Friday.
♂		Saturday.

JOURNAL of a Voyage from England, toward Madeira, in his Majesty's Ship the Neptune, LUCIUS MANLEY, Esq; Commander, kept by FRANCIS DRAKE, Master's Mate, 1772.

Winds.	REMARKS.
NW.b.W.	24. July 2d. At 2 P.M. the Pilot came on board; ordered the ship to be cast loose from the shear-hulk at Deptford, and made sail down the river. At 5 P.M. made fast to the shear-hulk at Woolwich, the wind not permitting us to proceed farther. At 4 A.M. cast loose from the hulk, and at 10 anchored in Long-Reach; moored with a cable each way*.
NE.	
NNW.	
NW.	2. July 3d. Employed taking the gunner's stores on board. Read the articles of war to the ship's company, and punished Simon Sturdy with 12 lashes, for drunkenness and disobedience. Fine weather and moderate wind.
W.b.S.	h. July 4th. Light airs and fine weather. A.M. unmoored, and sailed down the river to Gravesend. At noon anchored with the small bower † in 6 fathoms.
NNE.	©. July 5th. At 6 A.M. weighed and turned to windward down the reach; and at noon anchored in the Hope, in 7 fathoms. Fine weather and moderate wind.
Westerly.	D. July 6th. Brisk wind and cloudy weather. At 6 P.M. weighed and sailed; and at 2 A.M. anchored with the best bower at the Nore, in 9 fathoms. At 7 weighed and sailed.
NNW.	♂. July 7th. At 3 P.M. came to in Margate road with the best bower. At 8 A.M. weighed and made sail. Brisk wind and hazy weather.
Variable: westerly.	♀. July 8th. At 3 P.M. came to anchor in the Downs in 7 fathoms, and moored with a cable each way*. The town of Deal bearing WNW. and the South Foreland

† It is customary on board ships of war, as well as other ships that make long voyages, to have four large anchors, nearly of the same size, called the *small bower*, *best bower*, *sheet*, and *spare* anchors; the two first being always ready at the bows of the ship to moor with, or to let go as occasions require. The other two are suspended over the side farther aft, near the fore-chains, to be used along with the former in very bad weather, or to supply their places when they are lost. Beside these, each ship of war has three smaller anchors; namely, the stream anchor, which is about one-fourth part as big as one of the former, and two kedge-anchors, with cables and haulers proper for them, to be used in warping the ship from place to place, into and out of harbours, or to steady the ship on some occasions.

* When a ship is *moored*, she lies in the mid-way between two anchors; and when she is *moored with a cable each way*, the anchors are two cable lengths, or 200 fathoms asunder, and the ship rides in the mid-way between them. To place a ship thus in a stream, or in a tide's way, one of the bower anchors is let go, and the length of two cables veered out as the ship falls down the stream; the other bower is then let go, and the cable veered out as the other is hove in, until the ship is in the middle between the two anchors.

Journal

Journal from England toward Madeira, 1772.

Vinds.	REMARKS.
	S.W. b. S. sent the pilot on shore. Moderate wind, and cloudy with showers.
WN V.	21 July 9th. The former part of these 24 hours brisk wind and cloudy weather; the middle strong gales with rain. At 6 P. M. got down the top-gallant-yards. At 8 struck the yards, top-masts, and top-gallant masts. At 2 A. M. exceeding strong wind with rain: let go the sheet-anchor under foot.
NW.	22 July 10th. More moderate: P. M. hove up the sheet-anchor, and got up the yards and top-masts. A. M. overhauled the rigging, and set it up. Cloudy weather with some rain.
North.	23 July 11th. Brisk wind, and flying clouds. P. M. stowed the boats, cleared the decks, and made all ready for going to sea. At 6 A. M. unmoored. At 8 weighed and sailed; and at noon the South Foreland bore NW. distant 5 miles.

Journal from England toward Madeira.

H	K.	F.	Courses.	Winds.	Remarks on ☉, July 12th, 1772.
1	1	2	SSW. $\frac{1}{4}$ W.	N. $\frac{1}{2}$ W.	Little wind and fine weather.
2	1	2			Stowed the anchors. Set top-gallant sails and steering sails.
3	2				The South Foreland North.
4	3				
5	3	2	W. $\frac{1}{2}$ N.		
6	3	2			
7	3				Took in steering sails and top-gallant sails.
8	3			North.	Moderate wind and fine weather.
9	2	6			
10	2	6			
11	3	2			
12	3		West.	N. b. E.	Ditto weather.
1	3				
2	3	2	WNW. $\frac{1}{2}$ W.		Fairlight point N. b. W. about 4 miles.
3	3	2			Moderate wind and clear weather.
4	3	4			
5	3	6			Beachy head N. b. W. about 6 miles.
6	4	2			
7	5	4	W $\frac{1}{2}$ N.		Brisk gales and cloudy.
8	6	4			Took in a reef of each top-sail.
9	7				
10	7	4			
11	8				
12	8	4			Bembridge Point NW. 5 leagues.

Journal from England toward Madeira.

Ho.	K.	F.	Courses.	Winds.	Remarks on D, July 13th, 1772.		
1	7	6	WNW.	N. b. E.	Fresh gales and flying clouds.		
2	7	6	West.	North.	Dunnose WNW. about 7 miles.		
3	7	5			Ditto weather.		
4	7	4					
5	7	4					
6	7	4	WNW. $\frac{1}{2}$ W.	N. b. E.	The bill of Portland NW. b. N.		
7	7	6			Shortened sail.		
8	7	4					
9	6	2					
10	6				Weather as above.		
11	6						
12	6						
1	5	4			Moderate wind and clear.		
2	5	4					
3	5	2					
4	4						
5	4		WNW. $\frac{1}{2}$ N.	NNE.	The Start WNW. 4 leagues.		
6	4	2			Let out all reefs.		
7	6				Brisk wind and fine weather.		
8	6	4					
9	6	4					
10	6	4					
11	6	5			Merid. alt. $\odot$'s L. L. $61^{\circ} 28\frac{1}{2}'$ S.		
12	6	5			Ram-head NE. $\frac{1}{4}$ E.		
Courte.	Dif.	D. L.	Dep.	Lat. in.	Long. made.	Bearings and dist. at noon.	
S 31° W.	15	$12\frac{1}{2}$	$7\frac{1}{2}$	$50^{\circ} 5\frac{1}{2}'$ N.	$0^{\circ} 12'$ W.	Ram-h. NNE. $\frac{1}{4}$ E. 5 leag.	

Here the meridian alt. of the Sun's lower limb being $61^{\circ} 28\frac{1}{2}'$ S. the refraction (55) will be $30''$ to be subtracted. Suppose the height of the observer's eye to be 21 feet, and the dip of the horizon (55) will be $4' 22''$, to be subtracted also. By the same art. the Sun's semi-diameter on the 13th of July is $15' 47''$, to be added; consequently the correction of the ap. alt. of the Sun's l. l. will be $11'$ to be added: and the true alt. of his center was $61^{\circ} 39\frac{1}{2}'$: hence his true meridian zen. dist. was $28^{\circ} 20\frac{1}{2}'$ S.; and as the Sun's decl. for that day will be found $21^{\circ} 45'$ N. for the noon of a place 4° W. of London, the lat. of the ship at noon was $50^{\circ} 5\frac{1}{2}'$ N. The Ram-head lies in lat. $50^{\circ} 18'$ N.: the ship is therefore $12', 5$ south of the Ram-head. Moreover, the Ram-head bearing NE. $\frac{1}{4}$ E. by compass, the ship may be supposed to have sailed from thence SW. $\frac{3}{4}$ W.; or, because there are two points west variation in the Channel, SSW. $\frac{3}{4}$ W. true: now under $2\frac{3}{4}$ points in the traverse table; and against $12', 5$ in the diff. of lat. col. stands $15'$ nearly in the dist. col. for the distance which the ship was from the Ram-head at noon, and the true bearing of the Ram-head from her is NNE. $\frac{3}{4}$ E.

Again, the merid. parts to lat. $50^{\circ} 18'$, are 3502,6, and to $50^{\circ} 5\frac{1}{2}'$ 3483,1; of course the merid. diff. of lat. is 19,5, which being sought for in the diff. of lat. col. under $2\frac{3}{4}$ points in the trav. table, will be found to stand against $11', 8$ in the col. of dep.: $11', 8$, or $12'$, is therefore the diff. of long. which the ship is west of the merid. of the Ram-head, the Ram-head being NE. from it; and this is also the long. made in this case. Thus the ship's place is ascertained at noon, and her departure (as it is generally expressed) taken from the Ram-head.

But the method which seamen generally use in taking their departure from any point of land, is to set the point by the compass, and guess, as near as they can, how far the ship is from it. They then take the opposite point of the compass for the course which the ship may be supposed to have sailed from that point, correct it for variation of the compass (32), and with this course and the estimated dist. they find the diff. of lat. and dep. as in any other course, and dist., run by the log.

Journal

Journal from Eng. an d oward Madeira.

Ho.	K.	F.	Courses.	Winds.	Remarks on 6 th , July 14 th , 1772.
1	5	8	SW.	WNW.	Brisk wind and clear.
2	6				
3	6				
4	6				Wind as above: cloudy.
5	5	2			
6	3	4	SW. $\frac{1}{2}$ S.	WNW. $\frac{1}{2}$ W.	
7	3	4			
8	3	4	SW. b. S.	W. b. N.	Moderate wind and cloudy.
9	3				
10	2	2			
11	2	2			
12	1	6	SW. b. W.	NW. b. W.	Foggy, with drizzling rain.
1	2				
2	1	6			
3	2				
4	2				Ditto Weather.
5	2				
6	2				
7	1	6			
8	1	6			Tacked ship. Weather as above.
9	2		NW. $\frac{1}{2}$ N.	WSW. $\frac{1}{2}$ W.	
10	2				
11	1	6			
12	1	2			Light Breezes and foggy.
Course.	Dist.	D. L.	Dep.	Lat. in.	Long. made. Bearings and dist. at noon.
S. b. W.	59	58	11 $\frac{1}{2}$	49° 7 $\frac{1}{2}$ ' N.	0° 29 $\frac{1}{2}$ ' W. Ramh. N. 15° E. dist. 24 l.

Here, the ship being close on a wind, and making little way a-head, may be supposed to make a point and half lee-way: and the variation being two points westerly, her course by compass is altered $3\frac{1}{2}$ points, or the sum of these two toward the left hand, when on the star-board tack, and $\frac{1}{2}$ a point, or their diff. when on the larboard, to obtain the true courses put down in the first col. of the traverse table. The distances to each course are added up, reckoning 8 fathoms to make a knot, and put in the second col. against their respective courses; and the remaining part of the table is filled up by B. VII. art. 36.

In the traverse table (VII. 67.) I find that 58,2 stands in the diff. of lat. col. against 11,5 in the dep. col. under 11° in the courses; consequently the course made good by the ship for the whole day, is S. 11° W. Moreover, under this course, 58,2 stands in the diff. of lat. col. against somewhat more than 59 in the col. of distances, which is therefore the distance made good in the whole day.

Again, if from 50° 5 $\frac{1}{2}$ ' N. the lat. in yesterday at noon there be taken 58m. the diff. of lat. made since, S. there will remain 49° 7 $\frac{1}{2}$ ' N. for the lat. in this day at noon, by account, and which must be taken as the true lat. in. because there was no observation. The mer. parts to these two latitudes will be found 3483,1 and 3393,5: hence the mer. diff. of lat. is 89,6, which stands in the diff. of lat. col. (under 11°) against 17 $\frac{1}{2}$ in the dep. col. and 17 $\frac{1}{2}$ being added to 12', the long. made yesterday at noon, because both are W., gives 29 $\frac{1}{2}$ for the long. made this day at noon.

To find how the Ram-head bears, and its dist. from the ship, take 3393,5 the mer. parts to the ship's lat. from 3502,6 the mer. parts to the lat. of the Ram-head, and their diff. 109,1, will be found in the diff. of lat. col. against 29 $\frac{1}{2}$, the long. made, in the dep. col. under 15°; consequently the Ram-head bears N. 15° E. from the ship, because the ship is S. and W. from it. Lastly, 49° 7 $\frac{1}{2}$, ship's lat. being taken from 50° 18', lat. of the Ram-head, gives 70,5 diff. of lat.; which, under 15°, stands against the dist. 73 miles, or 24 $\frac{1}{2}$ leagues, the dist. required.

B b 4

Journal

The TRAVERSE TABLE.					
True course.	Dist.	N.	S.	E.	W.
S. $\frac{1}{2}$ W.	29	—	28,9	—	2,8
South.	7	—	7,0	—	—
S. $\frac{1}{2}$ E.	11	—	10,9	1,1	—
S. b. W. $\frac{1}{2}$ W.	17	—	16,3	—	4,9
NW.	7	4,9	—	—	4,9
		4,9	63,1	1,1	12,6
			4,9		1,1
			58,2		11,5

Journal from England toward Madeira.

Ho.	K.	F.	Courfes.	Winds.	Remarks on Q, July 15th, 1772.
1	2	4	NW. b. W.	SW. b. W.	Little wind, and foggy weather.
2	2				
3	2		NW.	WSW.	
4	2				Weather ditto.
5	1	6	NNW.	West.	
6	2				
7	1	4	NW. b. W.	SW. b. W.	
8	2				Tacked ship. Thick fog.
9	2	4	SSW.	West.	
10	2	4			
11	2	4	SW. b. S.	W. b. N.	
12	2	4			Weather as above.
1	1	6			
2	1	4			
3	1	4			
4	1	6	WSW.	NW.	Ditto Weather.
5	1	2	W. b. S.	NW. b. N.	
6	2				
7	1				
8	1	4			Very hazy: little wind.
9	2	2			
10	1	7	WSW.		
11	3		West.	North.	
12	4				Weath. do. mer. alt. ☉'s l. l. 62° 25' S.
Courfe.	Dis.	D. L.	Dep.	Lat. in.	Long. made. Bearings and dist. at noon.
S. 53° W.	29	17	23	48° 50 $\frac{1}{2}$ ' N.	1° 4 $\frac{1}{2}$ ' W. Ramh. N. 25° E. dist. 32 l.

By observing the directions given for working the two preceding day's works, the several operations will stand as follow. Noting only, that although the ship ran twice on a NW. b. W. course, viz. from noon to 2 o'clock, and from 6 to 8, yet that course is put down only once in forming the traverse table from the log., because as the ship is at the same dist. from the wind in both, and runs nearly at the same rate, the lee-way which she makes, and of consequence her true course, will be the same; but the distances which she ran both times are added into one sum, namely: 4 $\frac{1}{2}$ and 3 $\frac{1}{2}$ =8m. and put down against that course. On the contrary, when she runs twice WSW. that course is put down twice; because being close to the wind one time, and a point free the other, she would make more lee-way from 3 o'clock to 4, than she did from 9 to 10, and therefore the true courses would be different; 1 $\frac{1}{2}$ points being allowed in the former case, and only $\frac{1}{4}$ of a point in the latter.

Dip of the horizon	(55)	4' 22"
Refraction	(55)	0 30
Sum		4 52
Sun's semi-diameter	(55)	15 47
Difference		10 55
App. alt. ☉'s l. l.	62° 25' 00 S.	
True mer. alt. ☉'s cent.	62 35 55	
True zenith dist.	27 24 5 S.	
Sun's declination (V. 309)	21 26 10 N.	
Latitude observed	48 50 15 N.	
Lat. from 49° 07 $\frac{1}{2}$ ' mer. pts.	3393.5	
Lat. in. 48 50 mer. pts.	3366.9	
Diff. of long.	0° 35' W.	26.6
Long. from	0 29 $\frac{1}{2}$ W.	
Long. made	1 04 $\frac{1}{2}$ W.	

For the bearing and dist. at noon.

Lat. Ramh.	50° 18' N. mer. pts.	3502.6
Lat. in	48 50 N. mer. pts.	3366.9

Dist. 32 leag.	{ 1 28=88m.	2) 135.7	long. made=64.5m.
	{ N. 25° E.	67.85	half of each 32, 25

The TRAVERSE TABLE.					
True courfe.	Dist.	N.	S.	E.	W.
NW. b. W. $\frac{1}{2}$ W.	8	3.8			7.1
NW. $\frac{1}{2}$ W.	4	2.5			3.1
NNW. $\frac{1}{2}$ W.	4	3.5			1.9
S. b. E. $\frac{1}{2}$ E.	5		4.8	1.5	
S. $\frac{1}{2}$ E.	10		10.0	1.0	
SSW. $\frac{1}{2}$ W.	2		1.8		0.9
SW. b. S. $\frac{1}{2}$ W.	8		6.2		5.1
SW. b. S. $\frac{1}{4}$ W.	2		1.6		1.2
WSW.	7		2.7		6.5
		9.8	27.1	2.5	25.8
			9.8		2.5
Cour. S. 53° W. dist. 29m.			17.31		23.3
Lat. from	49 7 $\frac{1}{2}$ N.				
Lat. in by acc.	48 50 N.				

Journal

Journal from England toward Madeira.

Journal of the English						Remarks on 24, July 16th, 1772.	
Ho.	K.	F.	Courses.	Winds.			
1	3	6	W. b. S.	North.	Moderate wind and hazy.		
2	4	2	WSW.		A great swell from the NNE.		
3	6	Ditto weather.					
4	5	Shortened fail.					
5	5						
6	5						
7	4				The weather as above.		
8	3	4					
9	3	4					
10	4						
11	5						
12	5		NE.	Ditto weather.			
1	5						
2	4	4					
3	4				Moderate wind and flying clouds.		
4	4				Sun rose by compass N. 79° 30' E.		
5	4				Variation 22° 16' W.		
6	4				Set the top-gallant fails.		
7	3	5			Moderate wind and fine weather.		
8	3	5			Set the steering fails.		
9	3						
10	2	4					
11	3	3			The swell continues from the NNE.		
12	3	3			Dit. weath. Mer. alt. ☉'s l. l. 63° 37' S.		
Courte.		Dis.	D. L.	Dep.	Lat. in.	Long. made.	Bearings and dif. at noon.
S. 41° W.		108	81	71	47° 28' N.	2° 51½' W.	Ram-h. N. 34° E. dif. 68 l.

1. At 5 A. M. or 17h. it was 17 $\frac{1}{2}$ h. at Greenwich (57): at this time the sun's decl. was $21^{\circ} 19' N.$ By working the log. up to the time, the lat. of the ship will be found $47^{\circ} 49' N.$ Hence the true ampl. of the sun at rising was $N. 57^{\circ} 14' E.$; that by compass was observed above to be $79^{\circ} 30' E.$; consequently the variation is $22^{\circ} 16' W.$ (31) or two points nearly.

2. The swell setting from the NNE. toward the SSW. must carry the ship along with it; for this reason a SSW. course is introduced in the traverse, which variation allowed, is due S; and it is supposed the ship was set that way 12 miles in the 24 hours.

3. The true lat. observed will be found $47^{\circ} 28' N.$; and as that by account is $47^{\circ} 29' N.$ the diff. of lat. by observation, and not that by account, must be used with the departure in finding the course and dist. made good, and diff. of longitude.

Lat. fr. $48^{\circ} 50' N.$ Meridional parts 3366,9

Lat. in $47^{\circ} 28' N.$ Meridional parts 3244,0 Long. from $1^{\circ} 4\frac{1}{2}' W.$

Diff. lat. 1 $22^{\circ} 22' = 82m.$ } Mer. diff. lat. $= 122,9$ half $= 61,45$ } d. lon. 1 $47' W.$

Depart. 71m. } Gives the course S. $41^{\circ} W.$ } Longt. made 2 $51\frac{1}{2}' W.$

Lat. Ram-head $50^{\circ} 18' N.$ Meridional parts 3502,6; $\frac{1}{3}$ part is 57,2

Lat. ship $47^{\circ} 28' N.$ Meridional parts 3244,0

Diff. of lat. 2 $50'$ Mer. diff. lat. 258,6; $\frac{2}{3}$ part is 86,2

One third part 50,7. Hence the Ramh. bears N. $33\frac{1}{2}^{\circ} E.$ dist. 68 leag.

Here, because the meridional diff. of lat. and diff. of long. are greater than can be found in the table, one third of each is taken to find the course; then this course, and one third of the proper diff. of lat. give the distance in leagues.

Journal

Journal from England toward Madeira.

Ho.	K.	F.	Courses.	Winds.	Remarks on 9, July 17th, 1772.	
1	4		WSW.	NNW.	Moderate wind and clear. Hauled down	
2	4	2			lower steering fails.	
3	4	2				
4	4	2			Ditto weather.	
5	4					
6	3	3	SW. b. W.	NW.b.W.	Hauled down fore-top-mast steer. fails.	
7	4	3			Clued up and handed top-gallant fails.	
8	4	6			Weather as above.	
9	4					
10	4					
11	3	4			Moderate wind and cloudy.	
12	3					
1	3	4	SW. b. S.	W. b. N.		
2	3	4				
3	4					
4	4		NNW.	West.	Squally weather. Tacked ship.	
5	4					
6	3	2				
7	3					
8	3				Brisk wind and cloudy. Tacked.	
9	3	4	S. b. W.	W. b. S.		
10	4	4				
11	4					
12	4				Very hazy. Mer. alt. ☉'s l. l. 64° 30' S.	
Course.	Diff.	D. L.	Dep.	Lat. in.	Long. made.	Bearings and dist. at noon.
S 19° W.	67	58	20	46° 25' N.	3° 23½' W.	Ramh. N. 30° E. dist. 90 lea.

Working the traverse by the foregoing directions, the diff. of lat. will be 58,2 and the depart. 19,8, and hence the lat. by account will be $46^{\circ} 30' N$.: but the true lat. observed will be found only $46^{\circ} 25' N$. consequently the course by compass, or distance run by the log. or both, must be erroneous, and therefore the reckoning must be corrected by one of the three cases at Art. 81, 82, 83. Now 58,2 is found in the diff. of lat.

col. against 19,8 in the depart. col. under 19° ; which is therefore the course by account for the 24h. Consequently the correction must be made by art. 81. Now the diff. of lat. by observation is 63, with which, and the course by account S. $19^{\circ} W$. as the true course, find the dist. = 67 miles. Moreover, the mer. parts to the lat. from, and lat. in, are 3244,0 and 3151,7; consequently the mer. diff. of lat. will be 92,3, which under the course 19° , gives 32° for the diff. of longitude. The long. made is therefore $3^{\circ} 23\frac{1}{2}' W$. and the Ram-head will be found to bear N. $30^{\circ} E$. distant 90 leagues.

The TRAVERSE TABLE.

Course.	Diff.	N.	S.	E.	W.
SW.	21		14,9		14,9
S. b. W. $\frac{1}{2} W$.	27		25,8		7,8
S. $\frac{1}{2} E$.	15		14,9	1,5	
NNW. $\frac{1}{2} W$.	13	11,5			6,1
SSE. $\frac{1}{2} E$.	16		14,1	7,5	
		11,5	69,7	9,0	28,8
			11,5		9,0
			58,2		19,8

Journal from England toward Madeira.

Ho.	K.	F.	Courses.	Winds.	Remarks on 17, July 18th, 1772.	
1	4	5	South.	WSW.	Moderate wind, and hazy.	
2	4		S. b. E.	SW. b. W.		
3	3	2				
4	3		South.	WSW.	Ditto weather.	
5	3	2				
6	4		SSE.	SW.	Az. ☉'s cent. by comp. N. 53° 56' W.	
7	3		NW. b. N.	W. b. S.	Alt. of his l. l. 15° 56' var. obs. 22° 12' W.	
8	3				Weather as above,	
9	2		NW.	WSW.		
10	2					
11	1	5				
12	1	4			Rainy, unsettled weather.	
1	2	2	NW. b. N.	W. b. S.		
2	2	2				
3	2					
4	2				Squally, with rain.	
5	2	4				
6	3					
7	3					
8	2	6			Weather as above.	
9	2	4				
10	2	3	NNW.	West.		
11	2					
12	1	6			Foggy, with rain.	
Course.	Diff.	D. L.	Dep.	Latit. in.	Long. made.	Bearings and dist. at noon.
N 32° W	19	16½	10	46° 41½' N.	3° 38½' W.	Ramh. N. 33½° E. dist. 87 l.

1st. To work the azim. and from thence determine what var. must be allowed in correcting the courses. By art. 52, 53, 55, the true alt. of the Sun's cent. was 16° 4'. By V. 286, the Sun's decl. was 21° 3' N., and, working the log. up to the time, the lat. of the ship was 46° 10' N. Hence (28) the true azim. was N. 76° 8' W. and therefore the variat. (31) 22° 12' W.: consequently two points may still be allowed in correcting the courses.

2d. Having formed the traverse table, and worked the log. as in the margin, I find the diff. of lat. for the whole day is 16½ m. N. and the dep. 10,1 W. Hence the course made good is N. 32° W. and the distance 10 m. Moreover, the lat. by account is 46° 41½' N. and this is taken for the *lat. in*, as there was no observation. The mer. diff. of lat. is 24,0, which gives, under 32° in the courses, 15' for the diff. of long. Consequently the *long. made* is 3° 38½' W.

Lat. Ram-head 50° 18' N. mer. parts 3502,6

Lat. ship 46 41½ N. mer. parts 3175,7

Diff. of lat. 33 36½ 216,5 10) 326,9 Long. made = 10) 218,5

One third is 72,3 32,69 21,85

Hence dist. is 87 leagues. Bearing is N. 33½° E.

The TRAVERSE TABLE,

True course.	Diff.	N.	S.	E.	W.
SE. b. S. ½ E.	11		8,5	7,0	
SE. ½ E.	7		4,4	5,4	
SE. b. E. ½ E.	4		1,9	3,5	
NW. b. N. ½ W.	28	21,6			17,8
NW. ½ W.	7	4,4			5,4
NNW. ½ W.	6	5,3			2,8
		31,3	14,8	15,9	26,0
		14,8			15,9
Diff. of lat.		16,5			10,1
Lat. from	46° 25' N. m. pts.				3151,7
Lat. in	46 41½ N. m. pts.				3175,7
Diff. of long.	0 15 W. m. diff. lat. 24,0				
Long. from	3 23½ W.				
Long. made	2 38½ W.				

Journal

Journal from England toward Madeira.

Ho.	K.	F.	Courses.	Winds.	Remarks on ☉, July 19th, 1772.	
1	5	7	WSW.	NW.	Brisk wind and cloudy.	
2	3	4	S. W. $\frac{1}{2}$ W.			
3	2					
4	1	2			Moderate wind and cloudy weather.	
5	1	2				
6	3	3	SW. b. W.			
7	4	5				
8	4				The weather as above.	
9	4					
10	4					
11	4					
12	4				Ditto weather.	
1	3	4				
2	3	6				
3	3	4				
4	3	6			Ditto weather.	
5	3	6				
6	4					
7	3	5				
8	3	3			Brisk wind and cloudy.	
9	3	6	SW. $\frac{1}{2}$ W.			
10	3	3				
11	3	3				
12	4	2			Very hazy. Mer. alt. ☉'s l. l. $65^{\circ} 13'S$.	
Courfe.	Diff.	D. L.	Dep.	Latit. in.	Long. made.	Bearings & dist. at noon.
		74	43.4	$45^{\circ} 20'N$.	$4^{\circ} 44\frac{1}{2}'W$.	Kam-h. N. 33° E. d. 118. l.

A point is only allowed for lee-way on the WSW. course, because the ship went fast through the water. A quarter of a point only is allowed on the SW. b. W. course, because she was a point free; and none on the SW. $\frac{1}{2}$ W. course, as she was then $7\frac{1}{2}$ points from the wind.

On casting up the traverse table, it appears that the diff. of lat. is only 74 m. S., consequently the lat. by account is $45^{\circ} 27\frac{1}{2}'N$. whereas the true lat. observed will be found no more than $45^{\circ} 20'N$. Now to correct this error, and determine by which of the three cases (81, 82, 83.) it is to be done; as there has been no observation since the 17th, take the diff. of lat. made the 18th from that made the 19th, one being N. and the other S., and the remainder (57.7) will be the diff. of lat. made good on both days: also add the two departures together, because both are W., and the sum (53.5) is the departure for both days. This diff. of lat. and dep. give S. $43^{\circ}W$. for the course; the correction must therefore be made by Case III. This course by account and 65, diff. of lat. by observation, gives 60.6 depart., half the sum of this and that by account is 57.0; this depart. and 65 diff. of lat. by observation, give S. $41^{\circ}W$. for the true course. This course and 93.4, merid. diff. of lat. by observation give $81'$ diff. of long. for both days, which being added to $3^{\circ} 23\frac{1}{2}'$, the long. made on the 17th, gives $4^{\circ} 45'W$. for the long. made on the 19th. The bearing of the Ram-head N. 33° E. and dist. 118 leagues, will be found in the same manner as on the preceding days.

The TRAVERSE TABLE.					
True Course.	Diff.	N.	S.	E.	W.
SW. b. S.	6	—	5.0	—	3.3
SSW. $\frac{1}{4}$ W.	57	—	48.9	—	29.3
SSW. $\frac{1}{2}$ W.	23	—	20.3	—	10.8
Diff. of lat.	{ 74.2 — 43.4				
	{ 1 14 S.				
Latit. from	46 $41\frac{1}{2}'N$.				
Lat. in by acc.	45 $27\frac{1}{2}'N$.				

Journal

Journal from England toward Madeira.

Ho.	K.	F.	Courses.	Winds.	Remarks on D, July 20th, 1772.
1	4	4	SW. b.W.	NW. b. W.	Moderate wind and clear.
2	4	4			
3	3	4			
4	1	4			Light airs intermixed with calms.
5	1	2	SW.	WNW.	Tried the current which set W. b. N.
6	2	4			$\frac{1}{2}$ N. $\frac{3}{4}$ of a k. an ho.
7	3	4			Brisk wind and cloudy: took in a reef
8	3	5			of each top-fail.
9	3	4	SW. b.W.	NW. b. W.	
10	3	6			
11	2				Took in 2d reef of the top-fails.
12	3		S.W.	WNW.	Squally, with heavy rain.
1	2	5	SW. b. S.	W. b. N.	Handed the mizen top-fail.
2	2	5			Close reefed the fore top-fail.
3	2	3			
4	2	4			Squally, with showers.
5	3				
6	3	4	SSW.	West.	Close reefed the main top-fail.
7	4				
8	4				Heavy squalls of wind and foggy.
9	3		South.	WSW.	Saw Cape Ortagal S. b. E. about 7 leag.
10	2	6			
11	2				Handed the top fails.
12	2	2			Strong wind in squalls.
Course. Dist. D. L. Dep.			Lat. in.	Long. made.	Bearing and dist. at noon.
S 10° W.	68	67.2	11.3	44° 13' N.	5° 1' W Ramh. N. 29° E. dist. 139 l.

In working this day's log the following particulars must be observed.

Only $1\frac{1}{4}$ points are allowed for lee-way whilst the ship was running on the first SW. b. W. course, because, although she was close-hauled, she went well through the water, which may therefore be supposed to have been pretty smooth.

A point and half is allowed on the first SW. course, because we may presume the sea began to have more motion; and, moreover, toward the latter end of the time a reef of each top-fail was taken in.

The second time the ship went on these courses $1\frac{3}{4}$ points were allowed, because some part of the time the top-fails were double reefed: the same quantity is allowed on the SW. b. S. course. On the SSW. course two points were allowed, because the top-fails were close reefed; and three points were allowed when she went south, because the top-fails were handed part of the time.

The current setting WNW. $\frac{1}{2}$ W. by compass, or W. $\frac{1}{2}$ S. true, $\frac{3}{4}$ of a mile an hour, or 18 miles in the 24h; it is put down as if it was a course and dist. run by the ship, and worked as such. The remaining parts of this day's work are performed in the common manner; and the results will be found as they are put down under their proper titles above, the lat. by acc. being taken as the true lat. because there was no observation.

The TRAVERSE TABLE.

True Course.	Dist.	N.	S.	E.	W.
S. b. W. $\frac{3}{4}$ W.	14	—	13.2	—	4.7
S. $\frac{1}{2}$ W.	11	—	10.9	—	1.1
S. b. W. $\frac{1}{4}$ W.	9	—	8.7	—	2.2
S. $\frac{1}{4}$ W.	3	—	3.0	—	0.2
S. $\frac{3}{4}$ E.	13	—	12.9	1.9	—
SSE.	12	—	11.1	4.6	—
SE. b. E.	10	—	5.6	8.3	—
Curt. W. $\frac{1}{2}$ S.	18	—	1.8	—	17.9
Diff. latit.	{ 67.2 14.8 26.1				
	{ 1° 7' S. 14.8				
Latit. from	45 20 N. 11.3				
Latitude in	44 13 N.				

Journal from England toward Madeira.

Ho.	K.	F.	Courses.	Winds.	Remarks on ♂, July 21st, 1772.	
1	2		S. b. W.	W. b. S.	Strong wind and foggy.	
2	2					
3	2		NNW.	West.	Wore ship. C. Ortagal SW. 5 or 6 m.	
4	2				Weather as above.	
5	2					
6	2				Hauled up the main-sail.	
7	2				Brought too under the miz. stay-sail.	
8	Up NW.	off NNE.		Variable.		
9	Up NW.	off N. b. E.			Wore ship. Balanced the miz. & set it.	
10	Up NW.	b. W. off WSW.				
11	Up WNW.	off SW. b. W.			Set the fore-sail.	
12	3		WSW.	East.	More moderate.	
1	5				Set the main-sail.	
2	5					
3	5	4				
4	5	3			Moderate wind with rain.	
5	4				Set the top-fails.	
6	3					
7	3		W. b. S.		Let a reef out of the top-fails.	
8	3	4	West.		Moderate wind with rain.	
9	3					
10	2				Let out all reefs.	
11	2					
12	2				The Groyne Lights, SE. b. S. 4 or 5 lea.	
Courfe.	Dil.	D. L.	Dep.	Latit. in.	Long. made	Bearings and dist. at noon.
S. 52° W.	40	24.7	31½	43° 48' N.	5° 45' W.	Ramb. N. 31° E. dist. 15 al.

In working the log. for these 24 h. it is necessary to remark that 3½ points are allowed on the S. b. W. course, because both top-fails are handed: the like quantity is allowed on the NNW. course.

When a ship is brought to, as it is usually expressed, the tiller is put close over to leeward, which brings her head round to the wind. The wind having then very little power on the sails, the ship loses her way through the water, which ceasing to act on the rudder, her head falls off from the wind, the sail which she has set fills, and gives her fresh way through the water; which acting on the rudder brings her head again to the wind: thus the ship has a kind of vibratory motion, coming up to the wind and falling off from it again, alternately. Now the points of the compass which she comes up and falls off to, are noted, and put down in the log, in the manner they are above at the hours 8, 9, 10, 11, P. M. and the middle point between them taken for the ship's course; on which the proper lee-way and variation is to be allowed, and such distance as she may be supposed to drive. In the instances given above 6 points have been allowed for lee-way, and the ship has been supposed to drive a mile an hour. There is nothing particular in the remaining parts of this day's work: the several results are as put down under their respective titles.

The TRAVERSE TABLE.

True Course.	Diff.	N.	S.	E.	W.
SE. ½ E.	6	—	3,8	4,6	—
N. ½ W.	8	8,0	—	—	0,8
NE. b. N.	1	0,8	—	0,6	—
NNE. ½ E.	1	0,9	—	0,5	—
S. ½ W.	1	—	1,0	—	0,1
S. ½ E.	1	—	1,0	0,1	—
SW.	31	—	21,9	—	21,9
SW. b. W.	3	—	1,7	—	2,5
WSW.	13	—	5,0	—	12,0
		9,7	34,4	5,8	37,3
			9,7		5,8
Diff. of lat.			24' 7		31,5
Latitude from			44° 13' N.		
Latitude in			43° 48,3		

Journal from England toward Madeira.

Ho.	K.	F.	Courses.	Winds.	Remarks on 9, July 22d, 1772.			
1	}				Calm and cloudy.			
2								
3								
4								
5								
6								
7	}							
8					Calm and foggy.			
9		1	S. b. E.	SW. b. W.				
10		2						
11		2						
12		1			Little wind, and foggy.			
1	2		NW. $\frac{1}{2}$ N.	Variable.				
2	2	6						
3	3							
4	3	2			Ditto, and hazy.			
5	2		NNW.	West.				
6	2							
7	2		SSW.					
8	2				Ditto, and fine weather.			
9	2							
10	2							
11	2							
12	2				Flying clouds. Mer. alt. $\odot$'s l. l. $66^{\circ} 23' S.$			
Course.			Diff.	D. L.	Dep.	Latit. in.	Long. made	Bearings and dist. at noon.
			4		1,6	$43^{\circ} 35' N.$	$5^{\circ} 53' W.$	Ramh. N. $31^{\circ} E.$ dist. 157 lea.

The dip. of the horizon $4^{\circ} 22'$

Refraction (55) 25

Sum 4 47

The sun's semi-diam. 15 48

Difference 11 1

App. alt. $\odot$'s l. l. $66^{\circ} 23' 0 S.$ True alt. $\odot$'s center $66^{\circ} 34' 1$

Sun's zenith dist. 23 25 59 S.

Sun's declination 20 9 11 N.

Latitude observ. 43 35 10 N.

The latitude, by account, differing 9 miles from that observed, the reckoning must be corrected, as in the following operation.

	S.	W.
the 20th.	67,2	11,3
the 21st.	24,7	31,5
the 22d.	4,0	1,6

95,9 44,4, these give the course S. $25^{\circ} W.$; consequently

the correction must be made by Case 1. Art. 81.

Latitude from $45^{\circ} 20' N.$ Meridional parts 3058,3Latitude in $43^{\circ} 35' N.$ Meridional parts 2911,2True dif. lat. $105' = 1^{\circ} 45'$ Merid. diff. lat. 147,1 } Dif. of lon. $1^{\circ} 81' W.$ Course S. $25^{\circ} W.$ } Long. 19th 4 $44\frac{1}{2} W.$

Longit. made 5 53 W.

and the Ram-head will be found to bear N. $31^{\circ} E.$ and be dist. 157 leagues.*Journal*

The TRAVERSE TABLE.

True Course.	Dist.	N.	S.	E.	W.
SE. $\frac{1}{2}$ E.	6	—	3,8	4,6	—
NW.	11	7,8	—	—	7,8
NNW. $\frac{1}{2}$ W.	4	3,5	—	—	1,9
S. b. E. $\frac{1}{2}$ E.	12	—	11,5	3,5	—
		11,3	15,3	8,1	9,7
			11,3		8,1
Difference of latit.			4,0		1,6
Latitude from			$43^{\circ} 48' N.$		
Latit. by account			$43^{\circ} 44' N.$		

Journal from England toward Madeira.

No.	K.	F.	Courses.	Winds.	Remarks on 24, July 23d, 1772.		
1	3		WSW.	NNW.	Moderate wind, and hazy.		
2	3	6					
3	3						
4	2	6		North.	Ditto weather.		
5	2	4					
6	2	4	SW.				
7	2	4					
8	4			N. b. E.	Cape Finisterre SSW. 6 or 7 leagues.		
9	3	2					
10	3	6					
11	3	6					
12	3	6			Weather as above.		
1	3	6					
2	3	4					
3	3	4					
4	3	5			Moderate wind, and flying clouds.		
5	3	6					
6	4				About $\frac{1}{2}$ past 6 A. M. ob. the dist. of the nearest l. of the ☉ and ☾ $84^{\circ} 34' 25''$.		
7	4	4			App. alt. ☉'s l. l. $19^{\circ} 15\frac{1}{2}'$, the app. alt. of the ☾'s u. l. $59^{\circ} 00\frac{1}{2}'$. Hence the lon. of the ship by these ob. is $10^{\circ} 8' W$.		
8	5				Error of the acc. in long. $48\frac{1}{2}'$ too much.		
9	5				Merid. alt. ☉'s l. l. $67^{\circ} 28' S$.		
10	5						
11	5						
12	5						
Course.		Dist.	D. L.	Dep.	Lat. in.	Long. made.	Bearings and dist. at noon.
S. 28 $\frac{1}{2}$ W.		89	78	42	42 $^{\circ}$ 18' N.	6 $^{\circ}$ 50' W.	N. 30 $^{\circ}$ E. dist. 185 l.

The ship going large the whole 24h. no lee-way is to be allowed in working the log.

In deducing the longitude of the ship from the observed distance of the sun and moon, the sun's semi-diameter found in the Nautical Almanac is $15' 48''$, that of the moon $14' 55''$, and its augmentation, according to the altitude (56) $14''$; hence the apparent distance of their centers was $85^{\circ} 5' 22''$, the apparent altit. of the sun's center was $19^{\circ} 27'$, and that of the moon's $58^{\circ} 41'$: and it will be found

(109) that the arch A was $25^{\circ} 34'$, the first correction $+ 2' 13''$, the second $- 14' 00''$, and the third $+ 1''$. The true distance was therefore $84^{\circ} 53' 36''$, and (110) the time at Greenwich 19h. 14m. At this time the sun's declination was $19^{\circ} 59' 36'' N$. and by working the log up to $\frac{1}{2}$ past 6 A. M. the latitude will be found $42^{\circ} 42' N$. and, lastly, the true altit. of the sun was $19^{\circ} 24' 24''$: hence the time at the ship was 18h. 33m. 22s. and the long. $10^{\circ} 9\frac{1}{2}' W$.

It will be found, on working the log, that the ship made $44' W$. diff. of long. from noon, the preceding day to $\frac{1}{2}$ past 6 A. M. which gives $6^{\circ} 37' W$. for the long. made at the time of observation; add the long. of the Ram-head, $4^{\circ} 21' W$. and their sum, $10^{\circ} 58' W$. is the long. of the ship by account; consequently the reckoning of long. is too great by $48\frac{1}{2}'$.

Again, because Cape Finisterre bore SSW. by compass at 8 P. M., the ship was then under the same meridian. By working the log up to that time, the long. of the ship was $10^{\circ} 37\frac{1}{2}' W$. which is the long. of Cape Finisterre by account, and allowing $48\frac{1}{2}'$ for the error of account, there will remain $9^{\circ} 49' W$. for the long. of Cape Finisterre by the observation.

Journal

Journal from England toward Madeira.

Ho.	K.	F.	Courses.	Winds.	Remarks on ☉, July 24th, 1772.		
1	6		SW.		Brisk wind and clear weather.		
2	6						
3	6						
4	6				Weather as above.		
5	6						
6	6						
7	7				Observed azim. ☉'s cent. N. 50° 19' W.		
8	7				& the alt. of his l. l. 7° 56', var. 20° 9' W.		
9	6	6			Weather as above.		
10	6	4					
11	6	3					
12	7				Ditto weather.		
1	7						
2	6	4					
3	6						
4	6				Ditto weather.		
5	6						
6	6				About $\frac{1}{2}$ past 6 A. M. ob. dist. limbs sun		
7	6				& D 73° 13' 54", alt. ☉ l. l. 20° 25' $\frac{4}{5}$ alt.		
8	6				of D's u. l. 64° 41' $\frac{1}{5}$ long. ded. 11° 25'		
9	6				Brisk wind and clear weather. [$\frac{1}{4}$ W.		
10	6						
11	6						
12	6				Merid. alt. sun's l. l. 69° 31' S.		
Course.		Dif.	D. L.	Dep.	Lat. in.	Long. made.	Bearings and dif. at noon.
S. 25° W		150	136	63 $\frac{1}{2}$	40° 2' N.	8° 14' W.	Ram-h. N. 29° E. dif. 235 l.

1. At 7 h. ship's time, it was 7 $\frac{3}{4}$ h. at Greenwich (57) consequently the Sun's decl. from the Nautical Almanac was 19° 53' N. The corrected alt. of the sun will be found 8° 1', and the lat. of the ship, by working the log up to 7 h. 41° 39' N. Hence the true azimuth was N. 70° 28' W. and the variation of the compass 20° 9' W. And, allowing this variation, the work of the log for the whole day will be as in the margin: the two latitudes agreeing exactly. 2d. By working the log up to $\frac{1}{2}$ past 6 A. M. the lat. of the ship at that time will be found 40° 32' N. and the long. corrected according to yesterday's observation 11° 23' W. The estimate time at Greenwich will hence be 19 $\frac{1}{4}$ h, when the Sun's semi-diameter, in the Nautical Almanac, was 15' 48", that of the Moon 15' 2", her horizontal parallax 55' 11", and the augmentation of her diameter (56) 14". Hence the app. alt. of the ☉'s cent. will be found 20° 37', of the Moon's 64° 22', and the app. dist. of their centers 73° 44' 58". From these data, the arc A (109) will come out 30° 17' $\frac{1}{2}$, the 1st correction of the app. dist. + 2' 7", the second - 5' 38", the third + 0' 1", and, consequently, the true dist. 73° 41' 28"; which gives (110) 19 h. 28' 25" for the app. time at Greenwich when the dist. of the ☉ and ☾ was observed. At this time the declin. of the Sun will be found 19° 47' N. with which the lat. of the ship 40° 32' N. (as above) and 20° 35', the Sun's true alt. the time at the ship will be found 18 h 42' 25": the diff. of those times is 46' 0" = 11° 30' W. the long. of the ship, and therefore the error of account is by this observation 47' too much.

The TRAVERSE TABLE.

True Course.	Dif.	S.	W.
S. 25° W.	150	135.9	63.4
Diff. of lat.	2° 16' S.		
Lat. from	42 18 N.	2806,0	
Lat. in	40 02 N.	2625,3	
Diff. of long.	1° 24' W.	180,7	
Long. from	6 50 W.		
Long. made	8 14 W.		
Hence the Ram-head bore	N. 29° E.		
dif.	235 leagues.		

Journal from England toward Madeira.

Ho.	K.	F.	Courfes.	Winds.	Remarks on h, July 25th, 1772.
1	7		SW.	NE.	Brisk wind and clear weather.
2	6	4			
3	6	4			
4	7				Ditto weather.
5	7				
6	7	2			
7	7	4			
8	7				Brisk wind and hazy.
9	7				
10	7				
11	6	4	SW. b. W.		Ditto weather.
12	6	3			
1	6	4			
2	6	5			
3	6	4			
4	6	4			Ditto weather.
5	6	2			
6	6				
7	6				
8	6				Brisk wind and cloudy.
9	6		SW. b. S.		
10	6				
11	6				
12	6				Ditto weather, mer. alt. @'s l. l. 71° 40' S.
Courfe.	Dif.	D.L.	Dep.	Latit. in.	Long. made. Bearings and dist. at noon.
S. 25° W.	156	142	66	37° 40' N.	9° 39' W. Ram h. N. 28½° E. dif. 288 le.

This Day's work will stand as follows:

Dip of horizon (55)	4' 22"
Refraction (55)	0 18
Sum	4 40
Sun's semi-diam.	15 48
Difference	11 08
App. alt. @'s l. l.	71 40 00 S.
True alt. center	71 51 08
Zenith distance	18 8 52 S.
Sun's declination	19 30 56 N.
Latitude in	37 39 48 N.
Latitude from	40 2 0 N.
Diff. of lat. observed	2 22 12
Half the diff. of longitude	
Difference of longitude	1° 25 W.
Longitude from	8 14 W.
Longitude made	9 39 W.
Lat. Ram-head 50° 18' N.	Meridional parts 3502.6
Lat. of the ship 37 40 N.	Meridional parts 2443.0
Prop. dif. of lat. 12 38	Merid. dif. of lat. 1059.6
One-tenth part 75.8	Long. made = 9.39
One-tenth of dist. 86.5 miles	
Whole distance 288 leagues.	

The TRAVERSE TABLE.

True courfe.	Dif.	S.	W.
S. 25° W. {	100	90,63	42,26
S. 36 W. {	33	29,91	13,95
S. 14 W. {	12	9,71	7,05
	12	11,64	2,90
	2)	141,89	66,16
S. 25 W. {	78	70,94	33,08
	2		
Distance	156		

Meridional parts	2443,0
Meridional parts	2625,3
Merid. dif. of lat.	182,3
42½' half	91,15

1° 25 W.	
8 14 W.	
9 39 W.	
Meridional parts 3502.6	
Meridional parts 2443.0	
Merid. dif. of lat. 1059.6	Long. made = 9.39
105,96	57,9
Bearing	N. 28½° E.

Journal

Journal from England toward Madeira.

Ho.	K.	F.	Courfes.	Winds.	Remarks on ☉, July 26th, 1772.	
1	6		SW.	NE.	Brisk wind and cloudy.	
2	6	4				
3	6	4				
4	6	4			Brisk wind and cloudy.	
5	6	4				
6	6	4			Variation obferved by azimuth $17^{\circ} 11' W.$	
7	6	4				
8	6	6			Brisk wind and cloudy.	
9	6	4				
10	6	3				
11	6	3				
12	6	4			Brisk wind and flying clouds.	
1	5	4				
2	5	4				
3	5	4			Ditto weather.	
4	5	4			At 2m. 16f. after 4 A.M. by wa.ob.diff.far.	
5	6				l. of the ☽ from α Ariet. $40^{\circ} 33' 43''$, alt. of	
6	6				α Ar. $65^{\circ} 56'$, & that of the ☽'s l. l. $29^{\circ} 43\frac{1}{4}'$.	
7	6				At 6.32m. 44f. by wa.alt. ☉'s l. l. was $16^{\circ} 53'$.	
8	5	4			Weather as above.	
9	5	2			Saw a fail in the NE. quarter.	
10	5	2				
11	5	4				
12	5	6			Ditto weather, mer. alt. ☉'s l. l. $73^{\circ} 36' S$	
Course.	Diff.	D.L.	Dep.	Lat. in.	Long. made.	Bearings and diff. at noon.
S $28^{\circ} W.$	145	128	68	$35^{\circ} 30\frac{1}{3}' N.$	$10^{\circ} 12\frac{1}{4}' W.$	Ram-head N. $27^{\circ} E.$ diff. 332 leag. Funchal S. $36^{\circ} W.$ diff. 72 leagues.

The merid. alt. observed this day gives $35^{\circ} 30\frac{1}{3}' N.$ for the lat. The true diff. of lat. observed is therefore 129.7, which, with the dep. 68.1, gives S. $27^{\circ} \frac{1}{2}' W.$ for the true course; and this course with 161.4, the true merid. diff. of lat. gives 85 for the diff. of long. W. The long. made is therefore $11^{\circ} 4' W.$

In order to deduce the true long. of the ship from the observed dist. of the moon from α

Arietis, the app. time found from the alt. of the Sun at 6h. 32m. 44f. A. M. was 6h. 29m. 32f. consequently the watch was 3m. 12f. too fast, and therefore the app. time when the dist. was observed was 3h. 59m. 4f. or 15h. 59m. 4f. Hence the time at Greenwich was 17h. at which time the ☽'s horizontal parallax was $56' 26''$, her semi-diameter $15' 22''$, its augment according to her alt. $8''$, and consequently the app. dist. of the star from the ☽'s center was $40^{\circ} 18' 13''$, the app. alt. of her cent. $29^{\circ} 55'$, and that of the star $65^{\circ} 52'$. Hence the arch A comes out $38^{\circ} 38'$, the first correction— $19''$, the second— $44' 54''$, and the third $+3''$; therefore the true dist. was $39^{\circ} 33' 03''$, and (110.) the time at Greenwich 16h. 55m. 36f. the diff. between which and the time at the ship, found above, is 56m. 32f. = $14^{\circ} 8' W.$ But by working the log up to half past 6 A. M. the time when the Sun's alt. was taken, I find the long. of the ship by account was $15^{\circ} 8' W.$ the error of account is therefore, by this observation, one degree too much. By the first observation it was $48\frac{1}{2}'$, and by the second $47'$; the mean. of the three is $51\frac{3}{4}'$. It may hence be concluded that the true long. made this day at noon was only $10^{\circ} 12\frac{1}{4}' W.$ The bearing of the Ram-head will therefore be N. $27^{\circ} E.$ dist. 332 leagues, and that of Funchal in Madeira, the lat. of which is $32^{\circ} 36' N.$ and long. $17^{\circ} 06' W.$, S. $36^{\circ} W.$ dist. 72 leagues.

The TRAVERSE TABLE.

True course.	Dist.	S.	W.
S. $28^{\circ} W.$	145	128,0	68,1
Diff. of latitude		2	8 S.
Latitude from		37	40 N.
Lat. by account		35	32 N.

Journal from England toward Madeira.

Ho.	K.	F.	Courtes.	Winds.	Remarks on D, July 27th, 1772.	
1	5	4	SW.	NE.	Moderate wind and cloudy.	
2	5	4	SW. b. S.		Ditto Weather.	
3	5					
4	4	6				
5	4	3				
6	4	3				
7	4	6			Weather still as above.	
8	4	6				
9	4	5				
10	4	5				
11	5					
12	4	5			Moderate wind and hazy.	
1	5				Ditto weather.	
2	5					
3	4					
4	4					
5	4					
6	4	4			Moderate wind and hazy. At 9h. 13m. 4f. by watch the alt of the Sun's l. l. was $48^{\circ} 53\frac{3}{4}'$, and the az. of his cent. S. 63° E. At 11h. $45' 19''$ the alt. of his l. l. was $74^{\circ} 31'$. Cloudy weather.	
7	4	4				
8	4	2				
9	4	5				
10	5					
11	4	3				
12	4	6				
Courte.	Dis.	D. L.	Dep.	Latit. in.	Long. made.	Bearings and dist. at noon.
S 18° W.	116	110	34.7	$33^{\circ} 40'$ N.	$10^{\circ} 56\frac{3}{4}'$ W.	Ramh. N. $25\frac{1}{2}^{\circ}$ E. dist. 369 l.

Allowing $17^{\circ} W.$ variation, the traverse table will stand as in the margin where the lat. by account is $33^{\circ} 44' N.$

The first of the altitudes taken this forenoon, when corrected for dip of the horizon, refraction, and semi-diameter, will be $49^{\circ} 4\frac{1}{2}'$: the angle comprehended between the Sun's bearing at that time, and the course by compass, is 97° ; which, with 12 miles, the dist. run between the observations, give $1\frac{1}{2}$ diff. of

lat. to be subtracted; and therefore the first altitude, when reduced to what it would have been if observed where the second was, will be $49^{\circ} 3'$. The second altitude, when corrected for dip, &c. will be $74^{\circ} 42'$; the interval between the observations 2h. 32m. 15f. the lat. of the ship by account at the second observation was $33^{\circ} 45' N.$ and the Sun's declination $19^{\circ} 4\frac{1}{2}' N.$ Hence (75) the true lat. of the ship, at $\frac{3}{4}$ past 11 A.M. will be found $33^{\circ} 41' N.$: and as she made about a mile of southing afterwards, the true lat. of the ship at noon was $33^{\circ} 40' N.$ According to this, the true diff. of lat. was 110.3, with which, and the course $18^{\circ} W.$ found with the diff. of lat. and depart. by account, find the dist. 116m. This course, with 134.0, mer. diff. of lat. gives $43\frac{1}{2}'$ for the diff. of long.; and, therefore, taking the long. made yesterday to be $10^{\circ} 13\frac{1}{4}' W.$ as corrected by the lunar observations, the long. made this day will be $10^{\circ} 56\frac{3}{4}' W.$ and hence the Ram-head bore N. $25\frac{1}{2}^{\circ} E.$ and was dist. 369 leagues.

The TRAVERSE TABLE.

True course.	Diff.	S.	W.
$S. 28^{\circ} W.$	11	0.7	5.2
$S. 17^{\circ} W.$	101	96.6	29.5
		106.3	34.7
Diff. of lat.		$1^{\circ} 46\frac{1}{2}' S.$	
Lat. from		$35^{\circ} 30\frac{1}{2}' N.$	
Lat. by account		$33^{\circ} 44' N.$	

Journal from England toward Madeira.

Ho.	K.	F.	Courfes.	Winds.	Remarks on ♂, July 28th, 1772.			
1	4	2	SW.	NE.	Moderate wind and hazy.			
2	3	2	W. b. S.					
3	3	4						
4	3	6			Moderate wind and clear weather.			
5	3	6						
6	4	2						
7	4	2			Land feen from the maft-head, which we			
8	4	4	West.		take to be Porto Sancto.			
9	3	4			Weather as above.			
10	4							
11	3		W. $\frac{1}{2}$ S.					
12	3				Weather the fame.			
1	2							
2	1							
3	3							
4	3	2			Moderate wind and hazy.			
5	3	4						
6	3	4						
7	3	4						
8	3	4			Porto Sancto N. W. b. N.			
9	3				Weather as above.			
10	3	4	W b. S.	NNW.	Porto Sancto North.			
11	4	2			At noon Porto Sancto NE. $\frac{1}{2}$ E. Funchal in			
12	4	3			Madei. SW. b. W. Mer. alt. $\odot$'s l. l. $75^{\circ}50'S$.			
Course.			Dif.	D. L. Dep.	Lat. in.	Long. made.	Bearings and dift. at noon.	
S 54° W.			89	$51\frac{1}{2}$	73	$32^{\circ}48\frac{1}{2}'N$	$12^{\circ}23\frac{3}{4}'W$.	Funchal S. 39° W. dift. 5 lea.

In working the log. for these 24 h. 17° of west variation are allowed, and also 10° for lee-way on the latter W. b. S. course, because the ship was then only seven points from the wind. The traverse table will be as in the margin, where it appears that the diff. of latit. by the dead-reckoning will be only 37.7 m. whereas, by the observation, the ship has made 51.5 m. the latit. observed being $32^{\circ}48\frac{1}{2}'N$. To correct this, I find the course made good, according to the dead-reckoning, is S. $62\frac{1}{2}^{\circ}W$., the correction must therefore be made by Case II. (82). Now against 51.5, the diff. of lat. by observation, in the column of diff. of latitude, and against 72.7 in the depart. column, stands 89, in the dist. col. over $54\frac{1}{2}^{\circ}$ for the course. The sum of the lat. from and lat. in is $66^{\circ}28\frac{1}{2}'$; half of which is $33^{\circ}14\frac{1}{4}'$, the middle lat. and the compt. of this is $56^{\circ}45\frac{3}{4}'$; over which, as a course, and against 72.7, depart. stands 87 in the dist. col. for the diff. of long. and, consequently, the log. made this day at noon was $12^{\circ}23\frac{3}{4}'W$. Hence the Ram-head bore N. $27\frac{1}{2}^{\circ}E$. and was distant 394 leagues.

Again, Funchal, which is in latit. $32^{\circ}37'N$., bore SW. b. W. by compass; that is, S. $39^{\circ}W$. true: and, the latit. of the ship being $32^{\circ}48\frac{1}{2}'N$. the diff. of lat. was 11.5, and the meridional diff. of lat. 13.7: the ship was therefore 15 m. dist. from thence; and east of it in long. $11\frac{1}{4}$; consequently the longit. of Funchal, by this account is $16^{\circ}56'W$. of Greenwich.

APPENDIX,

Containing the Principles, upon which some of the preceding Precepts are founded.

124. I. *The Theory of Davis's Quadrant.* Plate XIV. Fig. 9.

To shew that the arcs $DF + HC$ make the zenith distance.

The line AH is horizontal.

Therefore the arc fBH = height of the Sun above the horizon.

Now the arc fBH = arc $FE + BH$.

Also the arc $dfc = 90^\circ$; = alt. and zen. dist. taken together.

Therefore the zen. dist. = arcs $fd + HC$ = arc $DF + HC$.

125. *Allowing the Sun's semidiameter in using the Shade vane.* Fig. 10.

AB represents the Sun, the center of which is c , and its rays pass over the top of an upright wall DE . It is evident, that no part of the Sun can be seen from a , and that the whole can but just be seen from b ; the shadow will therefore begin to terminate at a , and wholly end at b , going off gradually from total darkness at a to total brightness at b , neither the beginning nor end of this penumbral part being perceptible; consequently, neither the upper or lower limb can be observed accurately; but we shall be able to come nearer to one or the other, the brighter the Sun shines. On account of this uncertainty, seamen are obliged to take the middle Point between these, which gives the altitude, or zenith dist. of c , the center. Nothing, therefore, must be allowed for the Sun's semi-diameter.

126. II. *Of the Theory of Hadley's Quadrant.*

To what has already been said of this most excellent instrument, it has been judged proper to shew also, upon what principles it is constructed.

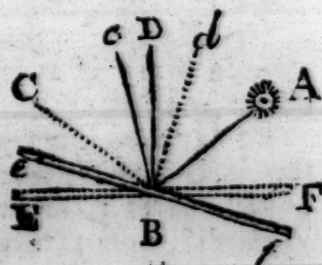
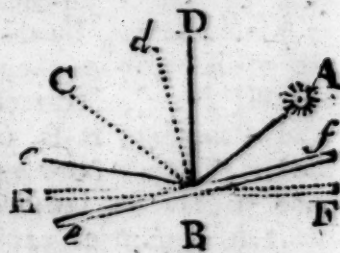
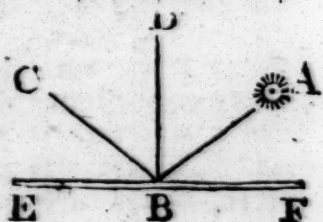
A ray of light AB falling on a mirror, or polished plane, EF , will be reflected in the line BC , so that the angle of reflection DBC , shall be equal to the angle of incidence DBA , DB being perpendicular to EF : or $\angle FBA$ is equal to $\angle EBC$.

Let the angle of incidence DBA , be 30° , the angle of reflection DBC will be 30° also; and the like in other inclinations.

If, while the radiant A remains in the same place, the mirror EF , by revolving round B , moves into the position fe ; then the alteration in the angle between the incident and reflected ray, will be double the angle shewing the change of position in the mirror.

Suppose the mirror changes 10° from the radiant, then the perpendicular BD goes 10° farther from the radiant A , into the position Bd ; and the incident angle dBA is 40° ; and the reflected angle dBc is 40° ; so the angle ABC is altered from 60° to 80° ; a difference of 20° , for 10° change of position in the mirror.

Suppose the mirror to change in position 10° towards the radiant A , then the perpendicular is changed into Bd , 10° nearer to the radiant.



And the angle DBA

130.

IV. *Of Refraction.*

Celestial objects, the nearer they are to the horizon, are seen through a larger portion of the atmosphere, and consequently have a greater quantity to be allowed for refraction, than when they are seen with greater altitudes.

Tables of refraction have been given by many astronomers, but that which is esteemed the most correct, was formed from the observations of the late celebrated Dr. Bradley; who also found a rule for correcting common tables of refraction: which is,

Increase any given altitude by thrice the refraction on that altitude.

Then to the log. co-tangent of that sum, add the log. 1,75587.

The sum lessened by 10 in the index is the log. number of seconds in the refraction; which is more correct than the table.

Here 1,75587 is the log. of 57'' the mean refraction on an alt. of 45°.

This rule is fitted to a mean warmth and weight of the atmosphere, viz. to the height 50 in Fahrenheit's Thermometer, and to the height 29,6 of the Barometer. For other states of the air, Dr. Bradley gave a rule for a farther correction; but it is apprehended, that neither of these corrections need be applied to the table of refractions, for any observations but such where there is wanted a precision not to be obtained at sea.

131.

V. *Demonstrations of the Rules at Articles 60, 61, 62.*

See Plate XIV. Figures 13, 14, 15.

Let the circle HZRN represent the meridian of the place, HR the horizon, and Z its zenith or pole: let PS represent the axis, P being the north, and S the south pole; the line EQ the equator, ☉ the place of the Sun, the arc Z ☉ the zenith distance, and E ☉ the declination.

Now the latitude is expressed either by the height of the pole above the horizon, or by the distance of the equator from the zenith; consequently the arc RP (=HS), or the arc ZE, being known will give the latitude.

But the arc ZE is always equal to the sum of the arcs Z ☉ and E ☉ when of contrary names; or to their difference when of the same name.

When the object does not set, its least altitude R ☉ added to the arc P ☉, or co-declination gives RP, the height of the pole above the horizon, or the latitude sought: the same may be understood, were the least altitude above the south point of the horizon to be observed. Fig. 15, 132. Hence it will be easy to construct any of these cases. Thus:

Set the zenith distance from Z, to the left if south, but to the right if north; and this gives ☉ the place of the Sun.

Set the declination from ☉, to the right if south, but to the left if north; and this gives E the place of the equator.

Then drawing the diameter EQ, and the diameter PS at right angles to EQ, the latitude will be north or south, according as P or S falls above the horizon.

133.

VI. Of Facio's Problem.

In the year 1728 Mr. *Nicholas Facio Duillier*, F. R. S. published a pamphlet, intitled, *Navigation Improved*, in which he considered more at large, than had been done before, the problem for finding the latitude from two observations of the Sun's altitude out of the meridian, with the time between them, which he states in the following terms.

134.

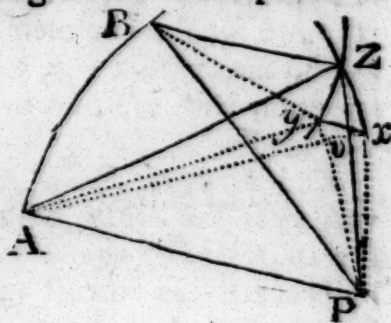
P R O B L E M.

To find the latitude, by two altitudes of the Sun, and the time between them, supposing the observations to have been made from the same place, or from different places, whether at sea or land. And likewise to find the hours, and the Sun's azimuths, at the times of both observations.

Thus he proposes expressly to distinguish between the case, when the two observations are made in the same place, and when, by the motion of the ship, in the interval between them, they are made under different zenith's; which does not appear to have been attempted before. He also extends the interval of time between the observations farther than is usually done, not confining them within the compass of one day; but makes them so remote, that the change in the Sun's declination may be necessary to be taken notice of.

His method of proceeding is this:

Supposing *P* the elevated pole, *A* and *B* the two places of the Sun, and *AP*, *PB*, *AB*, arcs of great circles passing through the points *P*, *A*, and *B*. Then if *PA* be the distance of the Sun from the pole *P* in the first observation, and *PB* its distance in the second, the angle *APB* corresponds to the time between the observations, whether that angle represents the whole interval of time, or only its difference from one or more entire days, *z* also denoting the zenith of the place, when both the observations are made under the same.



Here, if the interval of time be large, *AP* may be different from *PB*. Therefore in the triangle *APB* from *AP*, *BP*, and the angle *APB*, he finds the side *AB*; then from the three sides *AB*, *BP*, and *AB*, either of the angles *PAB*, *PBA* may be known; also from *AZ*, *ZB* and *AB* in the triangle *AZB*, either of the angles *ABZ*, *BAZ*; and in the last place, from these angles with *ABP*, or *BAP*, may be deduced the angle *ZAP* or *ZBP*, whence in either of the triangles *PAZ* or *PBZ*, *PZ* may be computed, the distance of the zenith *z* from the pole.

He likewise farther proposes to compute the angles *APZ*, *BPZ* for assigning the distance of each observation from noon, in order to determine the time of the day when they were respectively made.

All these trigonometrical operations he performs by one axiom (See Art. 251. Book IV.) in the doctrine of spherical triangles, which had been

been applied by others also, not only to the finding of an angle from three sides given, but likewise to the computing of the third side from two sides, and an angle between them.

But when the ship is in motion, z is not to be considered as the zenith of the ship in either observation. However, in the first observation the ship's zenith will always be in a circle described on A , as a pole, and with the interval AZ , suppose in x , and in the other observation will be in a circle described to the pole B with the interval BZ , suppose in y , the arch xy denoting the ship's course, making with the meridian of the first observation the angle Pxy .

This angle Pxy , and the length of the arc xy are to be assigned by the compass and log-line.

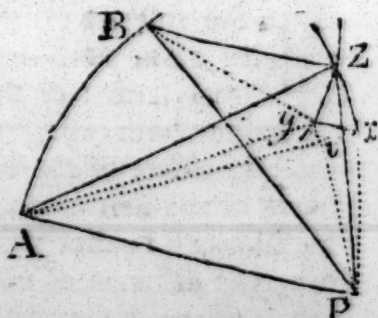
Now when the ship has been in motion during the interval between the observations, and these two additional *data* are added to the altitudes of the Sun, and the interval of time, *Facio* proceeds thus:

Having found the point z , as before, he computes in the triangle AZP , from AP , AZ , PZ , the angle AZP ; also in the triangle BZP from BP , BZ , PZ , the angle BZP , and from the angles AZP , BZP , the angle AZB , which (the angles AZx and Bzy being both right) will be equal to yzx .

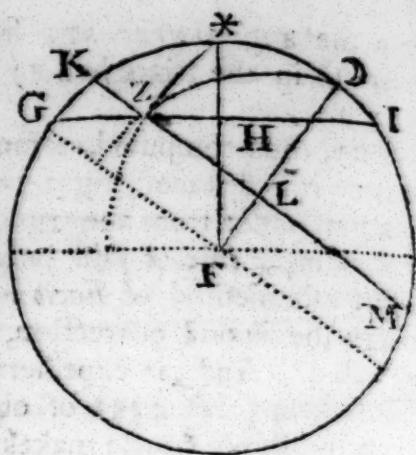
Then supposing the distance run xy to be so small an arch, that the triangle xzy may be considered as rectilinear without any sensible error; and also that the angle xpz is so small, that xy meeting pz in v , the angle pvy may be assumed, as not sensibly differing from the angle of the ship's course; whence the angle BZP having been computed, and thence the angle yzv known (Bzy being a right angle) from the angles yzv and zvy , the angle zyx , which is the complement of the angle which the ship's course makes with BZ , will be known; then from the angles xzy , zyx , together with the side yx , he finds the side zx ; and lastly, in the triangle pxz from xz , zp , and the angle xzp , the side px is found for the complement of the ship's latitude at the first observation; as also the angle zpx , and thence the angle APx , the distance of the observation with the Sun in A from the meridian, in which that observation was made.

And farther, *Facio* considering this computation, though it came very near the truth, as an approximation only, from the assumption of the angles yxp , and zvx , as equal, and the triangle zxy as rectilinear, he proceeds to correct the latitude, and the angle xpz thus found, as follows:

He assumes at pleasure two values for zx (or rather for the arch of a great circle passing through z and x) one somewhat greater, and the other somewhat less, than the value of zx now computed. Then for each value of zx , he finds in the triangle pxz from the sides pz , zx , and the angle pzx , the side px and angle xpz ; and in the triangle pxy from px now found with xy , and the angle pxy given from the course and distance run by the ship from x to y , he computes py , and the angle xpy . Then from



Now the triangle $z\delta*$ being projected orthographically on the circle passing through $\delta*$, as in the annexed figure, in which $F*$, $F\delta$ are drawn from the center F : through z let GH , perpendicular to $*F$, and KLM , perpendicular to $F\delta$, be drawn; then is Gz the versed sine, and zH the co-sine of the angle $z*G$, to the radius GH ; and also Kz the versed sine, and zL the co-sine of the angle $z\delta*$ to the radius KL ; moreover, FH is the co-sine of the arch $z*$ ($=*G$), and FL is the co-sine of the arch $z\delta$ ($=\delta K$), to the radius of the circle $G*\delta$.



Hence if in any circle lines as $F*$, $F\delta$, be drawn from the center, making an angle $*F\delta$ equal to the apparent distance of the Moon and star, and FH be taken equal to the sine of the star's altitude, and FL the sine of the Moon's altitude; the perpendiculars HG , and LK , being drawn intersecting each other in z , LK will be to Lz as the Moon's refraction, or parallax in altitude, to their effect on the distance. And in like manner GH will be to Hx , as the refraction of the star to the effect of that refraction on the distance of the star from the moon. But, moreover, in regard to the Moon's parallax, KL is the sine of the arch δz , the Moon's distance from the zenith, to the radius $F\delta$ of the circle; and consequently the Moon's horizontal parallax will be to the effect of her parallax on the distance from the star, as $F\delta$, the semidiameter of the circle, to Lz .

Upon these principles the two scales, relating to the parallax and the refraction, are to be constructed. But the method is attended with this inconvenience, that when the arch $\delta*$ is small, the lines Hx , Lz , will cross each other so very obliquely, as to make their true magnitude too uncertain; and this the author of the method seems not to have been unapprized of, by requiring that the distance should not be less than 10 degrees.

136. VIII. *Of the times of the Moon's phases, and the time of High Water.*

The methods given in Book VI. at Articles 130, 135, 136, for computing the Moon's age, southing, and time of high-water, frequently give those times many hours wide of the truth, and may occasion fatal accidents. It has therefore been judged proper to shew how the times of high-water are to be found more accurately, unless when the tides are made irregular by strong winds.

In the Nautical Almanac, the first page of every month contains the Moon's phases at Greenwich; which are easily transferred to any other place, the longitude of which is known, by the following

RULE. To the Greenwich time of the proposed phase apply the difference of longitude in time (57), and it will give the time of that phase at the place proposed.

EXAM. I. *At what times in May 1773 did the several phases of the Moon happen at Canton in China?*

Canton is E. of Greenwich ($113^{\circ} 1\frac{1}{2}' =$) 7h. 32m.

Then the times at Canton for the Moon's phases in May 1773, will be

Full Moon	6 d.	12 h.	34 m. (= 6 d. 5 h. 2 m. + 7 h. 32 m.)
Last Quarter	13	7	0
New Moon	21	10	15
First Quarter	29	4	55

EXAM. II. *At what times in March 1773 did the several phases of the Moon happen at Halifax in Nova Scotia?*

Halifax is west of Greenwich ($63^{\circ} 31' =$) 4 h. 14 m.

Then at Halifax the times of the phases required will be

First Quarter	1 d.	0 h.	17 m. (= 1 d. 4 h. 31 m. - 4 h. 14 m.)
Full Moon	8	6	41
Last Quarter	14	22	15
New Moon	22	12	8
First Quarter	30	17	45

137.

Of the time of High-water.

The times of high-water at the syzigies are nearly the same in most places; but the times of high-water from day to day between the syzigies do not alter 48 minutes, as is usually reckoned in pilotage; the difference being sometimes more, sometimes less, according as the waters are acted on, either by the sum of the attractive forces of the Sun and Moon, or by their difference, considered in respect to the places of the Earth and Moon relative to the Sun.

The following table * being used with the time of either phase of the Moon, will, in general, shew the time of high-water within a quarter of an hour of the truth at any known port, when the tides are not greatly influenced by the winds.

138.

TABLE.

Of the correction to be applied to the time of high-water on the syzigies, to give the time of high-water on any other day.

Interv. of time.	After n. moon	Before 1st qu.	After 1st qu.	Before f. moon	After f. moon	Before 3d qu.	After 3d qu.	Before n. moon	Interv. of time.
Addit.	Addit.	Addit.	Subtr.	Addit.	Addit.	Addit.	Addit.	Subtr.	
D. H.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	D. H.
0 0	0 0	5 6	5 6	0 0	0 0	5 6	5 6	0 0	0 0
6	0 8	4 51	5 22	0 9	0 8	4 51	5 22	0 9	6
12	0 17	4 37	5 40	0 18	0 17	4 37	5 40	0 18	12
18	0 26	4 23	6 0	0 27	0 26	4 23	6 0	0 27	18
1 0	0 36	4 9	6 20	0 37	0 36	4 9	6 20	0 37	1 0
6	0 45	3 56	6 39	0 47	0 45	3 56	6 39	0 47	6
12	0 54	3 44	6 58	0 57	0 54	3 44	6 58	0 57	12
18	1 2	3 32	7 18	1 7	1 2	3 32	7 18	1 7	18
2 0	1 11	3 21	7 37	1 17	1 11	3 21	7 37	1 17	2 0
6	1 19	3 11	7 56	1 28	1 19	3 11	7 56	1 28	6
12	1 28	3 1	8 14	1 39	1 28	3 1	8 14	1 39	12
18	1 37	2 50	8 31	1 51	1 37	2 50	8 31	1 51	18
3 0	1 46	2 40	8 47	2 4	1 46	2 40	8 47	2 4	3 0
6	1 54	2 30	9 2	2 16	1 54	2 30	9 2	2 16	6
12	2 3	2 21	9 17	2 29	2 3	2 21	9 17	2 29	12
18	2 12	2 12	9 31	2 44	2 12	2 12	9 31	2 44	18
4 0	2 21	2 3	9 44	2 58	2 21	2 3	9 44	2 58	4 0

If the time to be sought in this table is between the hours in the outside columns, the equation is to be corrected by proportional parts.

* From M. de la Caille.

PROPOSITION I.

139.

The time of high-water in any port on the syzigies, or days of new and full moon being known, to find the time of high-water in that port on any other day.

SOLUTION.

1st. In the Nautical Almanac, seek in the given month, or in that immediately preceding or following it, for the time of that phase which happens nearest to the given day; and take the difference of those times.

2d: In table (138.) this diff. of time gives an equation, which being applied to the time of the syzigie high-water for the given port (IV. 137) as its title directs, gives the time of the afternoon high-water in that port.

But if the time of the morning high water is required.

1st. Do as directed in the 1st article above, and increase the said diff. by 12 hours, if the given day falls before the phase.

Or diminish it by 12 hours, when after the phase.

2d. The equation to this time (138) applied to the syzigie time (IV. 137) gives the morning time of high-water.

EXAM. I. *At Portsmouth, where it is high-water on the syzigies at 11h. 15m.: Required the afternoon and morning times of high-water on the 13th of January, and on the 2d of February, in the year 1773.*

Here the nearest phase to January 13, is Jan. 15d. 10h. 10m.

So the time proposed is 2d. 10h. 10m. before the 3d or last quarter.

To 2d. 10h. and before 3d. 9h. the equation is 3h. 5m.

Then 11h. 15m. + 3h. 5m. = 14h. 20m. or high-water at 2h. 20m. P.M.

Again 2d. 10h. 10m. + 12h. = 2d. 22h. 10m. the eq. to which is 2h. 44m.

Then 11h. 15m. + 2h. 44m. = 13h. 59m. or high-water at 1h. 59m. A.M.

To Feb. 2d. the nearest phase is the 1st quarter, on Jan. 30d. 7h. 53m.

And as Feb. 2d. may be called

Jan. 33d.

Their diff. or time after the first quarter, is

2d. 16h. 7m.

The equation to which is 8h. 26m.

Then 11h. 15m. + 8h. 26m. = 19h. 41m. Or high-water at 7h. 41m. P.M.

Again 2d. 16h. 7m. — 12h. = 2d. 4h. 7m.; the eq. to which is 7h. 50m.

Then 11h. 15m. + 7h. 50m. = 19h. 5m. Or high-water at 7h. 5m. A.M.

EXAM. II. *On the 11th of March 1773, required the times of high-water at Halifax in Nova Scotia, where the syzigie time of high-water is at 7h. 30m.*

Halifax is W. of Greenwich ($63^{\circ} 20'$ =) 4h. 13m. 20s.

The nearest phase to March 11 is full moon, at 8d. 10h. 55m.

Which fitted to Halifax becomes

8d. 6h. 41m. 40s. (136)

March 11, is after full moon, 2d. 17h. 19m. its equation is 1h. 35m.

Then 7h. 30m. + 1h. 35m. = 9h. 5m. P.M. the time of high-water.

Again 2d. 17h. 19m. — 12h. = 2d. 5h. 19m.; its equation is 1h. 18m.

Then 7h. 30m. + 1h. 18m. = 8h. 48m. A.M. the time of high-water.

140.

PROPOSITION II.

The time of high-water in any port being observed on any day, to find the time of high-water in that port on the syzigies.

SOLUTION.

1st. By the difference of longitude reduce the given time to Greenwich time. (57)

2d. Take the difference between this time and that of the Moon's nearest phase. (136)

3d. The

3d. The equation in table, Art. 138. to this diff. applied to the said Greenwich time, contrary to what its title directs, will give the syzigie time of high water at that port.

EXAM. I. Suppose the time of high-water was observed in a port to be at 5h. P. M. when it wanted 3d. 17h. of the time of new moon; Required the time of high-water there on the day of new moon.

Now 3d. 17h. before new moon give an equation of 2h. 41m.

The column directs subtraction, the contrary is addition.

Then 5h. + 2h. 41m. = 7h. 41m. P. M. the syzigie time of high-water.

Also 3d. 17h. + 12h. = 4d. 5h. the equation to which is 3h. 10m. +

Then 5h. + 3h. 10m. = 8h. 10m. A.M. the time of new moon high-water.

EXAM. II. Suppose on the 19th of March, 1773, at 8h. 11m. P. M. it was observed to be high-water in the river Senegal? What is the time of high-water on the full and change days?

The river Senegal is west of Greenwich ($16^{\circ} 20' =$) 1h. 5m.

The nearest phase to March 19th, is the third quarter, at 15d. 2h. 29m. which fitted to Senegal, makes 15d. 1h. 24m.

The 19th day is after the third quarter, 3d. $22\frac{1}{2}$ h.; its equation is 9h. 41m. which is subtractive, contrary to its title in the table.

Then 8h. 11m. — 9h. 41m. = 10h. 30m. the time of high-water on the days of the full and change of the moon in the river Senegal.

141. Of the cause why the moon appears to rise nearly at the same time for several days together at some seasons of the year.

There are few mariners who have not observed at certain times, that the moon appears to rise or set for several days together at the same time nearly, notwithstanding that she is known to be retarded nearly 48 minutes in each day's motion.

This appearance arises chiefly from the daily alteration of 5 or 6 degrees in the moon's declination, when she is near the celestial equator. Now a change in the declination of celestial bodies will cause them to rise or set sooner or later, as well as when the observer changes his latitude.

Thus in the latitude of 50 degrees, when the Sun has 6° of declination, he rises at 5h. 31m.; but when he has no declination, he rises at 6 o'clock; so that a change of 6° in declination near the equinox accelerates the rising 29 minutes.

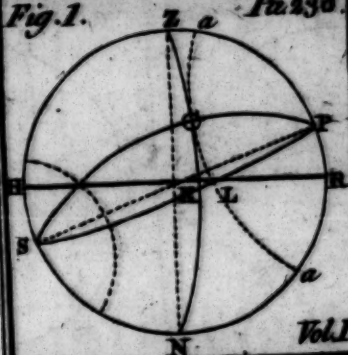
By a like change in the moon's declination her rising or setting may be quickened or delayed half an hour; but half an hour's acceleration diminishes a great part of the 48 minutes of daily retardation which she ought to have; and if to this be joined the apparent acceleration which may be caused by a less velocity in the motion of the moon near her apogee, and also that which may arise from an alteration of 3 or 4 degrees in the ship's latitude in 24 hours; it will follow, that the rising of the moon will not appear to be sensibly retarded for several days together.

Now the same cause which accelerates the rising retards the setting; so when the moon appears to rise for several days together about the same hour, its setting will appear to be retarded nearly the double of 48 minutes, or about an hour and half. On the contrary, if its setting is nearly about the same hour for several days, its rising will appear to be retarded almost double of its known daily motion.

Articles

Fig. 1.

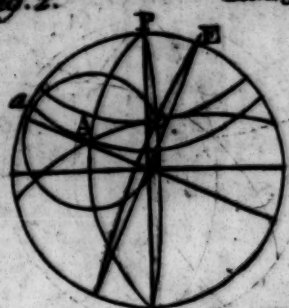
Pa. 238.



Vol. I.

Fig. 2.

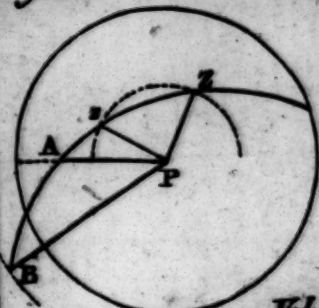
Pa. 238.



Vol. I.

Fig. 3.

Pa. 239.



Vol. I.

Fig. 5.

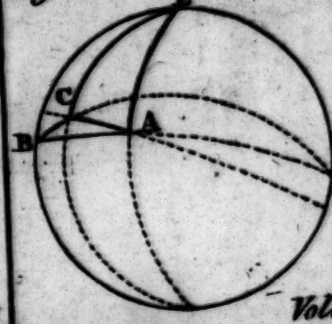
Pa. 240.



Vol. I.

Fig. 6.

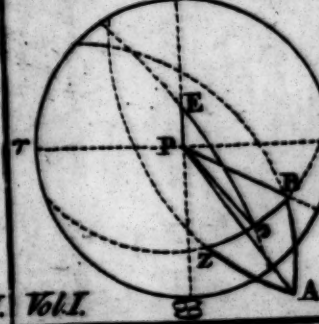
Pa. 240.



Vol. I.

Fig. 7.

Pa. 241.



Vol. I.

Fig. 9.

Pa. 294.
390

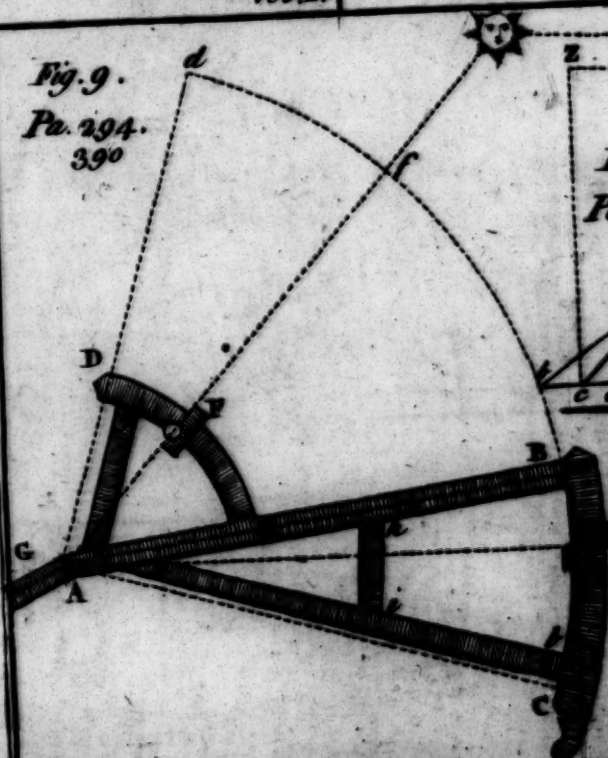


Fig. 10.

Pa. 390.

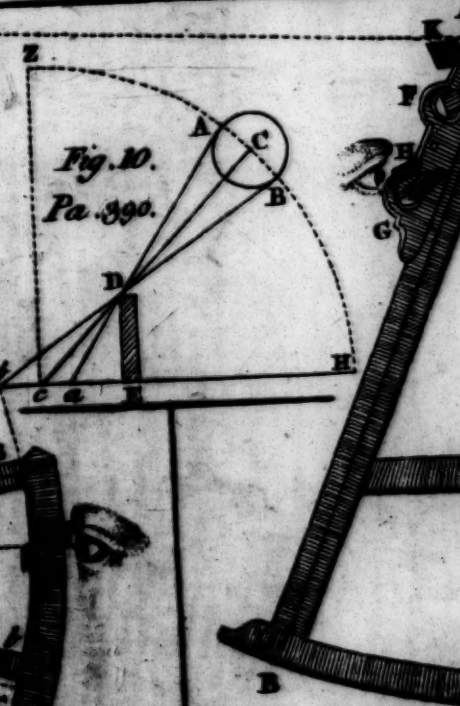


Fig. 12.

Pa. 391.

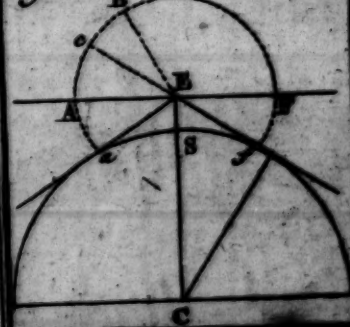


Fig. 13.

Pa. 392.

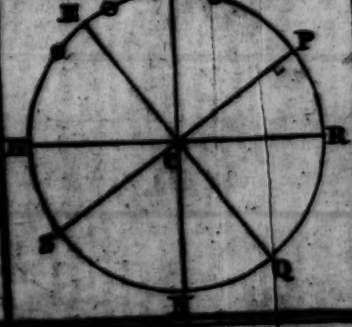


Fig. 14.

Pa.

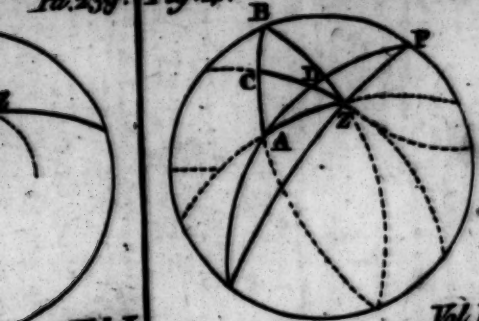


Pl. XIV.

Pa. 239.

Fig. 4.

Pa. 239.



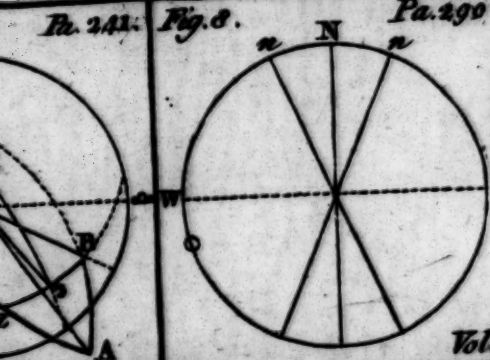
Vol. I.

Vol. I.

Pa. 241.

Fig. 8.

Pa. 290.



Vol. II.

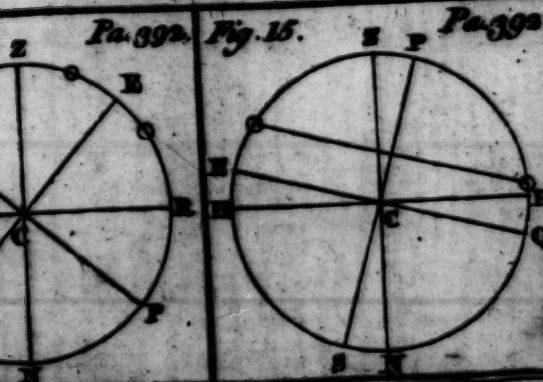
Fig. 11. Pa. 295.



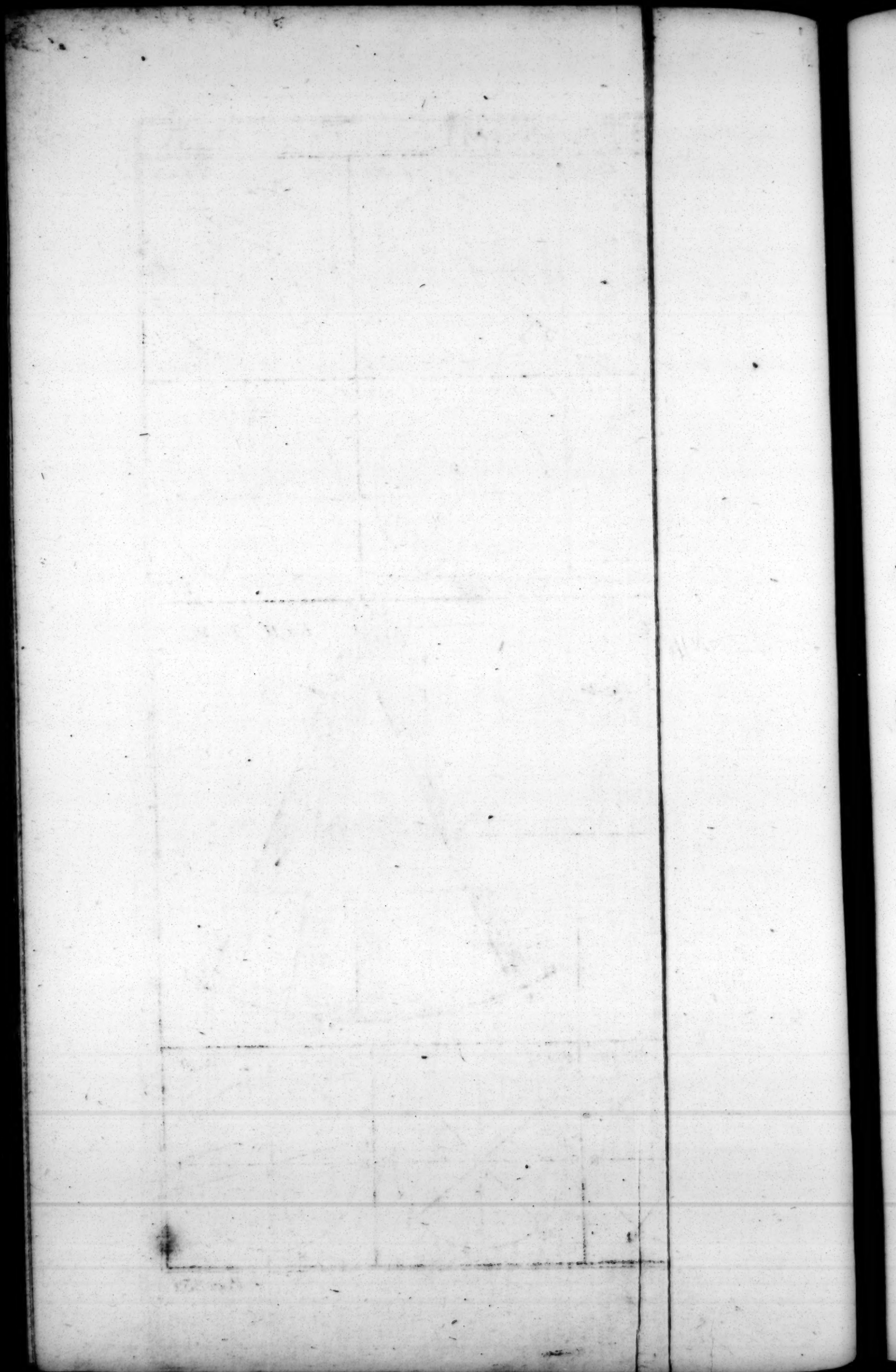
Pa. 392.

Fig. 15.

Pa. 392.



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Articles 142, 143, 144, 145.

LOGARITHMIC TABLES.

- I. The LOGARITHMS of NUMBERS from 1 to 120.
- II. The LOGARITHMIC SINES, TANGENTS and SECANTS, to every Point and Quarter-Point of the COMPASS.
- III. The LOGARITHMS of NUMBERS, from 100 to 10000.
- IV. The LOGARITHMS of the SINES and TANGENTS to every Degree and Minute of the QUADRANT.

354 • LOGARITHMIC TABLES.

142.

A T A B L E

Of Numbers and their Logarithms from 1 to 120.

N.	Log.	N.	Log.	N.	Log.	N.	Log.	N.	Log.	N.	Log.
1	0,00000	21	1,32222	41	1,61278	61	1,78533	81	1,90849	101	2,00432
2	0,30103	22	1,34242	42	1,62325	62	1,79239	82	1,91381	102	2,00860
3	0,47712	23	1,36173	43	1,63347	63	1,79934	83	1,91908	103	2,01284
4	0,60206	24	1,38021	44	1,64345	64	1,80618	84	1,92428	104	2,01703
5	0,69897	25	1,39794	45	1,65321	65	1,81291	85	1,92942	105	2,02119
6	0,77815	26	1,41497	46	1,66276	66	1,81954	86	1,93450	106	2,02531
7	0,84510	27	1,43136	47	1,67210	67	1,82607	87	1,93952	107	2,02938
8	0,90309	28	1,44716	48	1,68124	68	1,83251	88	1,94448	108	2,03342
9	0,95424	29	1,46240	49	1,69020	69	1,83885	89	1,94939	109	2,03743
10	1,00000	30	1,47712	50	1,69897	70	1,84510	90	1,95424	110	2,04139
11	1,04139	31	1,49136	51	1,70757	71	1,85126	91	1,95904	111	2,04532
12	1,07918	32	1,50515	52	1,71600	72	1,85733	92	1,96379	112	2,04922
13	1,11394	33	1,51851	53	1,72428	73	1,86332	93	1,96848	113	2,05308
14	1,14613	34	1,53148	54	1,73239	74	1,86923	94	1,97313	114	2,05690
15	1,17609	35	1,54407	55	1,74036	75	1,87506	95	1,97772	115	2,06070
16	1,20412	36	1,55630	56	1,74819	76	1,88081	96	1,98227	116	2,06446
17	1,23045	37	1,56820	57	1,75587	77	1,88649	97	1,98677	117	2,06819
18	1,25527	38	1,57978	58	1,76343	78	1,89209	98	1,99123	118	2,07188
19	1,27875	39	1,59106	59	1,77085	79	1,89763	99	1,99564	119	2,07555
20	1,30103	40	1,60206	60	1,77815	80	1,90309	100	2,00000	120	2,07918

143.

A T A B L E

Of Logarithmic Sines, Tangents and Secants, to every Quarter-Point of the Compass.

Pts.	Sines.	Co-sines.	Tangents.	Co-tang.	Secants.	Co-secan.	
0	0,00000	10,00000	0,00000	Infinite.	10,00000	Infinite.	8
0 $\frac{1}{4}$	8,69079	9,99948	8,69132	11,30868	10,00052	11,30921	7 $\frac{3}{4}$
0 $\frac{1}{2}$	8,99130	9,99790	8,99340	11,00660	10,00210	11,00870	7 $\frac{1}{2}$
0 $\frac{3}{4}$	9,16652	9,99527	9,17125	10,82875	10,00473	10,83348	7 $\frac{1}{4}$
1	9,29024	9,99157	9,29866	10,70134	10,00843	10,70976	7
1 $\frac{1}{4}$	9,38557	9,98679	9,39878	10,60122	10,01321	10,61443	6 $\frac{3}{4}$
1 $\frac{1}{2}$	9,46282	9,98088	9,48194	10,51806	10,01912	10,53718	6 $\frac{1}{2}$
1 $\frac{3}{4}$	9,52748	9,97384	9,55365	10,44635	10,02616	10,47252	6 $\frac{1}{4}$
2	9,58284	9,96562	9,61722	10,38277	10,03438	10,41716	6
2 $\frac{1}{4}$	9,63099	9,95616	9,67483	10,32517	10,04384	10,36901	5 $\frac{3}{4}$
2 $\frac{1}{2}$	9,67339	9,94543	9,72796	10,27204	10,05457	10,32661	5 $\frac{1}{2}$
2 $\frac{3}{4}$	9,71105	9,93335	9,77770	10,22230	10,06665	10,28895	5 $\frac{1}{4}$
3	9,74474	9,91985	9,82489	10,17511	10,08015	10,25526	5
3 $\frac{1}{4}$	9,77503	9,90483	9,87020	10,12980	10,09517	10,22497	4 $\frac{3}{4}$
3 $\frac{1}{2}$	9,80236	9,88819	9,91417	10,08583	10,11181	10,19764	4 $\frac{1}{2}$
3 $\frac{3}{4}$	9,82708	9,86979	9,95729	10,04271	10,13021	10,17292	4 $\frac{1}{4}$
4	9,84948	9,84948	10,00000	10,00000	10,15052	10,15052	4
	Co-sines.	Sines.	Co-tang.	Tangents.	Co-secan.	Secants.	Pts.

TABLE OF LOGARITHMS. 144. 355

Numbers from 100 to 1599. Logs. from ,00000 to ,20385.

No	0	1	2	3	4	5	6	7	8	9
100	,00000	,00043	,00087	,00130	,00173	,00217	,00260	,00303	,00346	,00389
101	,00432	,00475	,00518	,00561	,00604	,00647	,00689	,00732	,00775	,00817
102	,00860	,00903	,00945	,00988	,01030	,01072	,01115	,01157	,01199	,01242
103	,01284	,01326	,01368	,01410	,01452	,01494	,01536	,01578	,01620	,01662
104	,01703	,01745	,01787	,01828	,01870	,01912	,01953	,01995	,02036	,02078
105	,02119	,02160	,02202	,02243	,02284	,02325	,02366	,02407	,02449	,02490
106	,02531	,02572	,02612	,02653	,02694	,02735	,02776	,02816	,02857	,02898
107	,02938	,02979	,03019	,03060	,03100	,03141	,03181	,03222	,03262	,03302
108	,03342	,03383	,03423	,03463	,03503	,03543	,03583	,03623	,03663	,03703
109	,03743	,03782	,03822	,03862	,03902	,03941	,03981	,04021	,04060	,04100
110	,04139	,04179	,04218	,04258	,04297	,04336	,04376	,04415	,04454	,04493
111	,04532	,04571	,04610	,04650	,04689	,04727	,04766	,04805	,04844	,04883
112	,04922	,04961	,04999	,05038	,05077	,05115	,05154	,05192	,05231	,05269
113	,05308	,05346	,05385	,05423	,05461	,05500	,05538	,05576	,05614	,05652
114	,05690	,05729	,05767	,05805	,05843	,05881	,05918	,05956	,05994	,06032
115	,06070	,06108	,06145	,06183	,06221	,06258	,06296	,06333	,06371	,06408
116	,06446	,06483	,06521	,06558	,06595	,06633	,06670	,06707	,06744	,06781
117	,06819	,06856	,06893	,06930	,06967	,07004	,07041	,07078	,07115	,07151
118	,07188	,07225	,07262	,07298	,07335	,07372	,07408	,07445	,07482	,07518
119	,07555	,07591	,07628	,07664	,07700	,07737	,07773	,07809	,07846	,07882
120	,07918	,07954	,07990	,08027	,08063	,08099	,08135	,08171	,08207	,08243
121	,08279	,08314	,08350	,08386	,08422	,08458	,08493	,08529	,08565	,08600
122	,08636	,08672	,08707	,08743	,08778	,08814	,08849	,08884	,08920	,08955
123	,08991	,09026	,09061	,09096	,09132	,09167	,09202	,09237	,09272	,09307
124	,09342	,09377	,09412	,09447	,09482	,09517	,09552	,09587	,09621	,09656
125	,09691	,09726	,09760	,09795	,09830	,09864	,09899	,09934	,09968	,10003
126	,10037	,10072	,10106	,10140	,10175	,10209	,10243	,10278	,10312	,10346
127	,10380	,10415	,10449	,10483	,10517	,10551	,10585	,10619	,10653	,10687
128	,10721	,10755	,10789	,10823	,10856	,10890	,10924	,10958	,10992	,11025
129	,11059	,11093	,11126	,11160	,11193	,11227	,11260	,11294	,11327	,11361
130	,11394	,11428	,11461	,11494	,11528	,11561	,11594	,11628	,11661	,11694
131	,11727	,11760	,11793	,11826	,11860	,11893	,11926	,11959	,11992	,12024
132	,12057	,12090	,12123	,12156	,12189	,12222	,12254	,12287	,12320	,12352
133	,12385	,12418	,12450	,12483	,12516	,12548	,12581	,12613	,12646	,12678
134	,12710	,12743	,12775	,12808	,12840	,12872	,12905	,12937	,12969	,13001
135	,13033	,13066	,13098	,13130	,13162	,13194	,13226	,13258	,13290	,13322
136	,13354	,13386	,13418	,13450	,13481	,13513	,13545	,13577	,13609	,13640
137	,13672	,13704	,13735	,13767	,13799	,13830	,13862	,13893	,13925	,13956
138	,13988	,14019	,14051	,14082	,14114	,14145	,14176	,14208	,14239	,14270
139	,14301	,14333	,14364	,14395	,14426	,14457	,14488	,14520	,14551	,14582
140	,14613	,14644	,14675	,14706	,14737	,14768	,14799	,14829	,14860	,14891
141	,14922	,14953	,14983	,15014	,15045	,15076	,15106	,15137	,15168	,15198
142	,15229	,15259	,15290	,15320	,15351	,15381	,15412	,15442	,15473	,15503
143	,15534	,15564	,15594	,15625	,15655	,15685	,15715	,15746	,15776	,15806
144	,15836	,15866	,15897	,15927	,15957	,15987	,16017	,16047	,16077	,16107
145	,16137	,16167	,16197	,16227	,16256	,16286	,16316	,16346	,16376	,16406
146	,16435	,16465	,16495	,16524	,16554	,16584	,16613	,16643	,16673	,16702
147	,16732	,16761	,16791	,16820	,16850	,16879	,16909	,16938	,16967	,16997
148	,17026	,17056	,17085	,17114	,17143	,17173	,17202	,17231	,17260	,17289
149	,17319	,17348	,17377	,17406	,17435	,17464	,17493	,17522	,17551	,17580
150	,17609	,17638	,17667	,17696	,17725	,17754	,17782	,17811	,17840	,17869
151	,17898	,17926	,17955	,17984	,18013	,18041	,18070	,18099	,18127	,18156
152	,18184	,18213	,18241	,18270	,18298	,18327	,18355	,18384	,18412	,18441
153	,18469	,18498	,18526	,18554	,18583	,18611	,18639	,18667	,18696	,18724
154	,18752	,18780	,18808	,18837	,18865	,18893	,18921	,18949	,18977	,19005
155	,19033	,19061	,19089	,19117	,19145	,19173	,19201	,19229	,19257	,19285
156	,19312	,19340	,19368	,19396	,19424	,19451	,19479	,19507	,19535	,19562
157	,19590	,19618	,19645	,19673	,19700	,19728	,19756	,19784	,19811	,19838
158	,19866	,19893	,19921	,19948	,19976	,20003	,20030	,20058	,20085	,20112
159	,20140	,20167	,20194	,20222	,20249	,20276	,20303	,20330	,20358	,20385
No	0	1	2	3	4	5	6	7	8	9

356 TABLE OF LOGARITHMS. 144.

Numbers from 1600 to 2199. Logs. from ,20412 to ,34223.

Nº	0	1	2	3	4	5	6	7	8	9
160	,20412	,20439	,20466	,20493	,20520	,20547	,20575	,20602	,20629	,20656
161	,20683	,20710	,20736	,20763	,20790	,20817	,20844	,20871	,20898	,20925
162	,20951	,20978	,21005	,21032	,21059	,21085	,21112	,21139	,21165	,21192
163	,21219	,21245	,21272	,21299	,21325	,21352	,21378	,21405	,21431	,21458
164	,21484	,21511	,21537	,21564	,21590	,21617	,21643	,21669	,21696	,21722
165	,21748	,21775	,21801	,21827	,21854	,21880	,21906	,21932	,21958	,21985
166	,22011	,22037	,22063	,22089	,22115	,22141	,22167	,22194	,22220	,22246
167	,22272	,22298	,22324	,22350	,22376	,22401	,22427	,22453	,22479	,22505
168	,22531	,22557	,22583	,22608	,22634	,22660	,22686	,22712	,22737	,22763
169	,22789	,22814	,22840	,22866	,22891	,22917	,22943	,22968	,22994	,23019
170	,23045	,23070	,23096	,23121	,23147	,23172	,23198	,23223	,23249	,23274
171	,23300	,23325	,23350	,23376	,23401	,23426	,23452	,23477	,23502	,23528
172	,23553	,23578	,23603	,23629	,23654	,23679	,23704	,23729	,23754	,23779
173	,23805	,23830	,23855	,23880	,23905	,23930	,23955	,23980	,24005	,24030
174	,24055	,24080	,24105	,24130	,24155	,24180	,24204	,24229	,24254	,24279
175	,24304	,24329	,24353	,24378	,24403	,24428	,24452	,24477	,24502	,24527
176	,24551	,24576	,24601	,24625	,24650	,24674	,24699	,24724	,24748	,24773
177	,24797	,24822	,24846	,24871	,24895	,24920	,24944	,24969	,24993	,25018
178	,25042	,25066	,25091	,25115	,25139	,25164	,25188	,25212	,25237	,25261
179	,25285	,25310	,25334	,25358	,25382	,25406	,25431	,25455	,25479	,25503
180	,25527	,25551	,25575	,25600	,25624	,25648	,25672	,25696	,25720	,25744
181	,25768	,25792	,25816	,25840	,25864	,25888	,25912	,25935	,25959	,25983
182	,26007	,26031	,26055	,26079	,26102	,26126	,26150	,26174	,26198	,26221
183	,26245	,26269	,26293	,26316	,26340	,26364	,26387	,26411	,26435	,26458
184	,26482	,26505	,26529	,26553	,26576	,26600	,26623	,26647	,26670	,26694
185	,26717	,26741	,26764	,26788	,26811	,26834	,26858	,26881	,26905	,26928
186	,26951	,26975	,26998	,27021	,27045	,27068	,27091	,27114	,27138	,27161
187	,27184	,27207	,27231	,27254	,27277	,27300	,27323	,27346	,27370	,27393
188	,27416	,27439	,27462	,27485	,27508	,27531	,27554	,27577	,27600	,27623
189	,27646	,27669	,27692	,27715	,27738	,27761	,27784	,27807	,27830	,27852
190	,27875	,27898	,27921	,27944	,27967	,27989	,28012	,28035	,28058	,28081
191	,28103	,28126	,28149	,28171	,28194	,28217	,28240	,28262	,28285	,28307
192	,28330	,28353	,28375	,28398	,28421	,28443	,28466	,28488	,28511	,28533
193	,28556	,28578	,28601	,28623	,28646	,28668	,28691	,28713	,28735	,28758
194	,28780	,28803	,28825	,28847	,28870	,28892	,28914	,28937	,28959	,28981
195	,29003	,29026	,29048	,29070	,29092	,29115	,29137	,29159	,29181	,29203
196	,29226	,29248	,29270	,29292	,29314	,29336	,29358	,29380	,29403	,29425
197	,29447	,29469	,29491	,29513	,29535	,29557	,29579	,29601	,29623	,29645
198	,29667	,29688	,29710	,29732	,29754	,29776	,29798	,29820	,29842	,29863
199	,29885	,29907	,29929	,29951	,29973	,29994	,30016	,30038	,30060	,30081
200	,30103	,30125	,30146	,30168	,30190	,30211	,30233	,30255	,30276	,30298
201	,30320	,30341	,30363	,30384	,30406	,30428	,30449	,30471	,30492	,30514
202	,30535	,30557	,30578	,30600	,30621	,30642	,30664	,30685	,30707	,30728
203	,30750	,30771	,30792	,30814	,30835	,30856	,30878	,30899	,30920	,30942
204	,30963	,30984	,31006	,31027	,31048	,31069	,31091	,31112	,31133	,31154
205	,31175	,31197	,31218	,31239	,31260	,31281	,31302	,31323	,31345	,31366
206	,31387	,31408	,31429	,31450	,31471	,31492	,31513	,31534	,31555	,31576
207	,31597	,31618	,31639	,31660	,31681	,31702	,31723	,31744	,31765	,31785
208	,31806	,31827	,31848	,31869	,31890	,31911	,31931	,31952	,31973	,31994
209	,32015	,32035	,32056	,32077	,32098	,32118	,32139	,32160	,32181	,32201
210	,32222	,32243	,32263	,32284	,32305	,32325	,32346	,32366	,32387	,32408
211	,32428	,32449	,32469	,32490	,32510	,32531	,32552	,32572	,32593	,32613
212	,32634	,32654	,32675	,32695	,32715	,32736	,32756	,32777	,32797	,32818
213	,32838	,32858	,32879	,32899	,32919	,32940	,32960	,32980	,33001	,33021
214	,33041	,33062	,33082	,33102	,33122	,33143	,33163	,33183	,33203	,33224
215	,33244	,33264	,33284	,33304	,33325	,33345	,33365	,33385	,33405	,33425
216	,33445	,33465	,33486	,33506	,33526	,33546	,33566	,33586	,33606	,33626
217	,33646	,33666	,33686	,33706	,33726	,33746	,33766	,33786	,33806	,33826
218	,33846	,33866	,33885	,33905	,33925	,33945	,33965	,33985	,34005	,34025
219	,34044	,34064	,34084	,34104	,34124	,34143	,34163	,34183	,34203	,34223
Nº	0	1	2	3	4	5	6	7	8	9

TABLE OF LOGARITHMS. 144. 357

Numbers from 2200 to 2799. Logs. from ,34242 to ,44700.

N ^o	0	1	2	3	4	5	6	7	8	9
220	,34242	,34262	,34282	,34301	,34321	,34341	,34361	,34380	,34400	,34420
221	,34439	,34459	,34479	,34498	,34518	,34537	,34557	,34577	,34596	,34616
222	,34635	,34655	,34674	,34694	,34713	,34733	,34753	,34772	,34792	,34811
223	,34830	,34850	,34869	,34889	,34908	,34928	,34947	,34967	,34986	,35005
224	,35025	,35044	,35064	,35083	,35102	,35122	,35141	,35160	,35180	,35199
225	,35218	,35238	,35257	,35276	,35295	,35315	,35334	,35353	,35372	,35392
226	,35411	,35430	,35449	,35468	,35488	,35507	,35526	,35545	,35564	,35583
227	,35603	,35622	,35641	,35660	,35679	,35698	,35717	,35736	,35755	,35774
228	,35793	,35813	,35832	,35851	,35870	,35889	,35908	,35927	,35946	,35965
229	,35984	,36003	,36021	,36040	,36059	,36078	,36097	,36116	,36135	,36154
230	,36173	,36192	,36211	,36229	,36248	,36267	,36286	,36305	,36324	,36342
231	,36361	,36380	,36399	,36418	,36436	,36455	,36474	,36493	,36511	,36530
232	,36549	,36568	,36586	,36605	,36624	,36642	,36661	,36680	,36698	,36717
233	,36736	,36754	,36773	,36791	,36810	,36829	,36847	,36866	,36884	,36903
234	,36922	,36940	,36959	,36977	,36996	,37014	,37033	,37051	,37070	,37088
235	,37107	,37125	,37144	,37162	,37181	,37199	,37218	,37236	,37254	,37273
236	,37291	,37310	,37328	,37346	,37365	,37383	,37401	,37420	,37438	,37457
237	,37475	,37493	,37511	,37530	,37548	,37566	,37585	,37603	,37621	,37639
238	,37658	,37676	,37694	,37712	,37731	,37749	,37767	,37785	,37803	,37822
239	,37840	,37858	,37876	,37894	,37912	,37931	,37949	,37967	,37985	,38003
240	,38021	,38039	,38057	,38075	,38093	,38112	,38130	,38148	,38166	,38184
241	,38202	,38220	,38238	,38256	,38274	,38292	,38310	,38328	,38346	,38364
242	,38382	,38399	,38417	,38435	,38453	,38471	,38489	,38507	,38525	,38543
243	,38561	,38578	,38596	,38614	,38632	,38650	,38668	,38686	,38703	,38721
244	,38739	,38757	,38775	,38792	,38810	,38828	,38846	,38863	,38881	,38899
245	,38917	,38934	,38952	,38970	,38987	,39005	,39023	,39041	,39058	,39076
246	,39094	,39111	,39129	,39146	,39164	,39182	,39199	,39217	,39235	,39252
247	,39270	,39287	,39305	,39322	,39340	,39358	,39375	,39393	,39410	,39428
248	,39445	,39463	,39480	,39498	,39515	,39533	,39550	,39568	,39585	,39602
249	,39620	,39637	,39655	,39672	,39690	,39707	,39724	,39742	,39759	,39777
250	,39794	,39811	,39829	,39846	,39863	,39881	,39898	,39915	,39933	,39950
251	,39967	,39985	,40002	,40019	,40037	,40054	,40071	,40088	,40106	,40123
252	,40140	,40157	,40175	,40192	,40209	,40226	,40243	,40261	,40278	,40295
253	,40312	,40329	,40346	,40364	,40381	,40398	,40415	,40432	,40449	,40466
254	,40483	,40500	,40518	,40535	,40552	,40569	,40586	,40603	,40620	,40637
255	,40654	,40671	,40688	,40705	,40722	,40739	,40756	,40773	,40790	,40807
256	,40824	,40841	,40858	,40875	,40892	,40909	,40926	,40943	,40959	,40976
257	,40993	,41010	,41027	,41044	,41061	,41078	,41095	,41111	,41128	,41145
258	,41162	,41179	,41196	,41212	,41229	,41246	,41263	,41280	,41296	,41313
259	,41330	,41347	,41363	,41380	,41397	,41414	,41430	,41447	,41464	,41481
260	,41497	,41514	,41531	,41547	,41564	,41581	,41597	,41614	,41631	,41647
261	,41664	,41681	,41697	,41714	,41731	,41747	,41764	,41780	,41797	,41814
262	,41830	,41847	,41863	,41880	,41896	,41913	,41929	,41946	,41963	,41979
263	,41996	,42012	,42029	,42045	,42062	,42078	,42095	,42111	,42127	,42144
264	,42160	,42177	,42193	,42210	,42226	,42243	,42259	,42275	,42292	,42308
265	,42325	,42341	,42357	,42374	,42390	,42406	,42423	,42439	,42455	,42472
266	,42488	,42504	,42521	,42537	,42553	,42570	,42586	,42602	,42619	,42635
267	,42651	,42667	,42684	,42700	,42716	,42732	,42749	,42765	,42781	,42797
268	,42813	,42830	,42846	,42862	,42878	,42894	,42911	,42927	,42943	,42959
269	,42975	,42991	,43008	,43024	,43040	,43056	,43072	,43088	,43104	,43120
270	,43136	,43152	,43169	,43185	,43201	,43217	,43233	,43249	,43265	,43281
271	,43297	,43313	,43329	,43345	,43361	,43377	,43393	,43409	,43425	,43441
272	,43457	,43473	,43489	,43505	,43521	,43537	,43553	,43569	,43584	,43600
273	,43616	,43632	,43648	,43664	,43680	,43696	,43712	,43727	,43743	,43759
274	,43775	,43791	,43807	,43823	,43838	,43854	,43870	,43886	,43902	,43917
275	,43933	,43949	,43965	,43981	,43996	,44012	,44028	,44044	,44059	,44075
276	,44091	,44107	,44122	,44138	,44154	,44170	,44185	,44201	,44217	,44232
277	,44248	,44264	,44279	,44295	,44311	,44326	,44342	,44358	,44373	,44389
278	,44404	,44420	,44436	,44451	,44467	,44483	,44498	,44514	,44529	,44545
279	,44560	,44576	,44592	,44607	,44623	,44638	,44654	,44669	,44685	,44700
N ^o	0	1	2	3	4	5	6	7	8	9

358 TABLE OF LOGARITHMS. 144

Numbers from 2800 to 3399. Logs. from ,44716 to ,53135.

Nº	0	1	2	3	4	5	6	7	8	9
280	,44716	,44731	,44747	,44762	,44778	,44793	,44809	,44824	,44840	,44855
281	,44871	,44886	,44902	,44917	,44932	,44948	,44963	,44979	,44994	,45010
282	,45025	,45040	,45056	,45071	,45086	,45102	,45117	,45133	,45148	,45163
283	,45179	,45194	,45209	,45225	,45240	,45255	,45271	,45286	,45301	,45317
284	,45332	,45347	,45362	,45378	,45393	,45408	,45423	,45439	,45454	,45469
285	,45484	,45500	,45515	,45530	,45545	,45561	,45576	,45591	,45606	,45621
286	,45637	,45652	,45667	,45682	,45697	,45712	,45728	,45743	,45758	,45773
287	,45788	,45803	,45818	,45834	,45849	,45864	,45879	,45894	,45909	,45924
288	,45939	,45954	,45969	,45984	,46000	,46015	,46030	,46045	,46060	,46075
289	,46090	,46105	,46120	,46135	,46150	,46165	,46180	,46195	,46210	,46225
290	,46240	,46255	,46270	,46285	,46300	,46315	,46330	,46344	,46359	,46374
291	,46389	,46404	,46419	,46434	,46449	,46464	,46479	,46494	,46509	,46523
292	,46538	,46553	,46568	,46583	,46598	,46613	,46627	,46642	,46657	,46672
293	,46687	,46702	,46716	,46731	,46746	,46761	,46776	,46790	,46805	,46820
294	,46835	,46849	,46864	,46879	,46894	,46909	,46923	,46938	,46953	,46967
295	,46982	,46997	,47012	,47026	,47041	,47056	,47070	,47085	,47100	,47114
296	,47129	,47144	,47159	,47173	,47188	,47202	,47217	,47232	,47246	,47261
297	,47276	,47290	,47305	,47319	,47334	,47349	,47363	,47378	,47392	,47407
298	,47422	,47436	,47451	,47465	,47480	,47494	,47509	,47524	,47538	,47553
299	,47567	,47582	,47596	,47611	,47625	,47640	,47654	,47669	,47683	,47698
300	,47712	,47727	,47741	,47756	,47770	,47784	,47799	,47813	,47828	,47842
301	,47857	,47871	,47885	,47900	,47914	,47929	,47943	,47958	,47972	,47986
302	,48001	,48015	,48029	,48044	,48058	,48073	,48087	,48101	,48116	,48130
303	,48144	,48159	,48173	,48187	,48202	,48216	,48230	,48244	,48259	,48273
304	,48287	,48302	,48316	,48330	,48344	,48359	,48373	,48387	,48401	,48416
305	,48430	,48444	,48458	,48473	,48487	,48501	,48515	,48530	,48544	,48558
306	,48572	,48586	,48601	,48615	,48629	,48643	,48657	,48671	,48686	,48700
307	,48714	,48728	,48742	,48756	,48770	,48785	,48799	,48813	,48827	,48841
308	,48855	,48869	,48883	,48897	,48911	,48926	,48940	,48954	,48968	,48982
309	,48996	,49010	,49024	,49038	,49052	,49066	,49080	,49094	,49108	,49122
310	,49136	,49150	,49164	,49178	,49192	,49206	,49220	,49234	,49248	,49262
311	,49276	,49290	,49304	,49318	,49332	,49346	,49360	,49374	,49388	,49402
312	,49415	,49429	,49443	,49457	,49471	,49485	,49499	,49513	,49527	,49541
313	,49554	,49568	,49582	,49596	,49610	,49624	,49638	,49651	,49665	,49679
314	,49693	,49707	,49721	,49734	,49748	,49762	,49776	,49790	,49803	,49817
315	,49831	,49845	,49859	,49872	,49886	,49900	,49914	,49927	,49941	,49955
316	,49969	,49982	,49996	,50010	,50024	,50037	,50051	,50065	,50079	,50092
317	,50106	,50120	,50133	,50147	,50161	,50174	,50188	,50202	,50215	,50229
318	,50243	,50256	,50270	,50284	,50297	,50311	,50325	,50338	,50352	,50365
319	,50379	,50393	,50406	,50420	,50433	,50447	,50461	,50474	,50488	,50501
320	,50515	,50529	,50542	,50556	,50569	,50583	,50596	,50610	,50623	,50637
321	,50650	,50664	,50678	,50691	,50705	,50718	,50732	,50745	,50759	,50772
322	,50786	,50799	,50813	,50826	,50839	,50853	,50866	,50880	,50893	,50907
323	,50920	,50934	,50947	,50961	,50974	,50987	,51001	,51014	,51028	,51041
324	,51054	,51068	,51081	,51095	,51108	,51121	,51135	,51148	,51162	,51175
325	,51188	,51202	,51215	,51228	,51242	,51255	,51268	,51282	,51295	,51308
326	,51322	,51335	,51348	,51362	,51375	,51388	,51402	,51415	,51428	,51441
327	,51455	,51468	,51481	,51495	,51508	,51521	,51534	,51548	,51561	,51574
328	,51587	,51601	,51614	,51627	,51640	,51654	,51667	,51680	,51693	,51706
329	,51720	,51733	,51746	,51759	,51772	,51786	,51799	,51812	,51825	,51838
330	,51851	,51865	,51878	,51891	,51904	,51917	,51930	,51943	,51957	,51970
331	,51983	,51996	,52009	,52022	,52035	,52048	,52061	,52075	,52088	,52101
332	,52114	,52127	,52140	,52153	,52166	,52179	,52192	,52205	,52218	,52231
333	,52244	,52257	,52270	,52283	,52297	,52310	,52323	,52336	,52349	,52362
334	,52375	,52388	,52401	,52414	,52427	,52440	,52453	,52466	,52479	,52492
335	,52504	,52517	,52530	,52543	,52556	,52569	,52582	,52595	,52608	,52621
336	,52634	,52647	,52660	,52673	,52686	,52699	,52711	,52724	,52737	,52750
337	,52763	,52776	,52789	,52802	,52815	,52827	,52840	,52853	,52866	,52879
338	,52892	,52905	,52917	,52930	,52943	,52956	,52969	,52981	,52994	,53007
339	,53020	,53033	,53046	,53058	,53071	,53084	,53097	,53110	,53122	,53135
Nº	0	1	2	3	4	5	6	7	8	9

TABLE OF LOGARITHMS. 144. 359

Numbers from 3400 to 3999. Logs. from ,53148 to ,60195.

Nº	0	1	2	3	4	5	6	7	8	9
340	,53148	,53161	,53173	,53186	,53199	,53212	,53224	,53237	,53250	,53263
341	,53275	,53288	,53301	,53314	,53326	,53339	,53352	,53364	,53377	,53390
342	,53403	,53415	,53428	,53441	,53453	,53466	,53479	,53491	,53504	,53517
343	,53529	,53542	,53555	,53567	,53580	,53593	,53605	,53618	,53631	,53643
344	,53656	,53668	,53681	,53694	,53706	,53719	,53732	,53744	,53757	,53769
345	,53782	,53794	,53807	,53820	,53832	,53845	,53857	,53870	,53882	,53895
346	,53908	,53920	,53933	,53945	,53958	,53970	,53983	,53995	,54008	,54020
347	,54033	,54045	,54058	,54070	,54083	,54095	,54108	,54120	,54133	,54145
348	,54158	,54170	,54183	,54195	,54208	,54220	,54233	,54245	,54258	,54270
349	,54283	,54295	,54307	,54320	,54332	,54345	,54357	,54370	,54382	,54394
350	,54407	,54419	,54432	,54444	,54456	,54469	,54481	,54494	,54506	,54518
351	,54531	,54543	,54555	,54568	,54580	,54593	,54605	,54617	,54630	,54642
352	,54654	,54667	,54679	,54691	,54704	,54716	,54728	,54741	,54753	,54765
353	,54777	,54790	,54802	,54814	,54827	,54839	,54851	,54864	,54876	,54888
354	,54900	,54913	,54925	,54937	,54949	,54962	,54974	,54986	,54998	,55011
355	,55023	,55035	,55047	,55060	,55072	,55084	,55096	,55108	,55121	,55133
356	,55145	,55157	,55169	,55182	,55194	,55206	,55218	,55230	,55242	,55255
357	,55267	,55279	,55291	,55303	,55315	,55328	,55340	,55352	,55364	,55376
358	,55388	,55400	,55413	,55425	,55437	,55449	,55461	,55473	,55485	,55497
359	,55509	,55522	,55534	,55546	,55558	,55570	,55582	,55594	,55606	,55618
360	,55630	,55642	,55654	,55666	,55678	,55691	,55703	,55715	,55727	,55739
361	,55751	,55763	,55775	,55787	,55799	,55811	,55823	,55835	,55847	,55859
362	,55871	,55883	,55895	,55907	,55919	,55931	,55943	,55955	,55967	,55979
363	,55991	,56003	,56015	,56027	,56038	,56050	,56062	,56074	,56086	,56098
364	,56110	,56122	,56134	,56146	,56158	,56170	,56182	,56194	,56205	,56217
365	,56229	,56241	,56253	,56265	,56277	,56289	,56301	,56312	,56324	,56336
366	,56348	,56360	,56372	,56384	,56396	,56407	,56419	,56431	,56443	,56455
367	,56467	,56478	,56490	,56502	,56514	,56526	,56538	,56549	,56561	,56573
368	,56585	,56597	,56608	,56620	,56632	,56644	,56656	,56667	,56679	,56691
369	,56703	,56714	,56726	,56738	,56750	,56761	,56773	,56785	,56797	,56808
370	,56820	,56832	,56844	,56855	,56867	,56879	,56891	,56902	,56914	,56926
371	,56937	,56949	,56961	,56972	,56984	,56996	,57008	,57019	,57031	,57043
372	,57054	,57066	,57078	,57089	,57101	,57113	,57124	,57136	,57148	,57159
373	,57171	,57183	,57194	,57206	,57217	,57229	,57241	,57252	,57264	,57276
374	,57287	,57299	,57310	,57322	,57334	,57345	,57357	,57368	,57380	,57392
375	,57403	,57415	,57426	,57438	,57449	,57461	,57473	,57484	,57496	,57507
376	,57519	,57530	,57542	,57553	,57565	,57576	,57588	,57600	,57611	,57623
377	,57634	,57646	,57657	,57669	,57680	,57692	,57703	,57715	,57726	,57738
378	,57749	,57761	,57772	,57784	,57795	,57807	,57818	,57830	,57841	,57852
379	,57864	,57875	,57887	,57898	,57910	,57921	,57933	,57944	,57955	,57967
380	,57978	,57990	,58001	,58013	,58024	,58035	,58047	,58058	,58070	,58081
381	,58092	,58104	,58115	,58127	,58138	,58149	,58161	,58172	,58184	,58195
382	,58206	,58218	,58229	,58240	,58252	,58263	,58274	,58286	,58297	,58309
383	,58320	,58331	,58343	,58354	,58365	,58377	,58388	,58399	,58410	,58422
384	,58433	,58444	,58456	,58467	,58478	,58490	,58501	,58512	,58524	,58535
385	,58546	,58557	,58569	,58580	,58591	,58602	,58614	,58625	,58636	,58647
386	,58659	,58670	,58681	,58692	,58704	,58715	,58726	,58737	,58749	,58760
387	,58771	,58782	,58794	,58805	,58816	,58827	,58838	,58850	,58861	,58872
388	,58883	,58894	,58906	,58917	,58928	,58939	,58950	,58961	,58973	,58984
389	,58995	,59006	,59017	,59028	,59040	,59051	,59062	,59073	,59084	,59095
390	,59106	,59118	,59129	,59140	,59151	,59162	,59173	,59184	,59195	,59207
391	,59218	,59229	,59240	,59251	,59262	,59273	,59284	,59295	,59306	,59318
392	,59329	,59340	,59351	,59362	,59373	,59384	,59395	,59406	,59417	,59428
393	,59439	,59450	,59461	,59472	,59483	,59494	,59506	,59517	,59528	,59539
394	,59550	,59561	,59572	,59583	,59594	,59605	,59616	,59627	,59638	,59649
395	,59660	,59671	,59682	,59693	,59704	,59715	,59726	,59737	,59748	,59759
396	,59770	,59780	,59791	,59802	,59813	,59824	,59835	,59846	,59857	,59868
397	,59879	,59890	,59901	,59912	,59923	,59934	,59945	,59956	,59966	,59977
398	,59988	,59999	,60010	,60021	,60032	,60043	,60054	,60065	,60076	,60086
399	,60097	,60108	,60119	,60130	,60141	,60152	,60163	,60173	,60184	,60195
Nº	0	1	2	3	4	5	6	7	8	9

360 TABLE OF LOGARITHMS. 144.

Numbers from 4000 to 4599. Logs. from ,60206 to ,66266.

N ^o	0	1	2	3	4	5	6	7	8	9
400	,60206	,60217	,60228	,60239	,60245	,60260	,60271	,60282	,60293	,60304
401	,60314	,60325	,60336	,60347	,60358	,60369	,60379	,60390	,60401	,60412
402	,60423	,60433	,60444	,60455	,60466	,60477	,60487	,60498	,60509	,60520
403	,60530	,60541	,60552	,60563	,60574	,60584	,60595	,60606	,60617	,60627
404	,60638	,60649	,60660	,60670	,60681	,60692	,60703	,60713	,60724	,60735
405	,60746	,60756	,60767	,60778	,60788	,60799	,60810	,60820	,60831	,60842
406	,60853	,60863	,60874	,60885	,60895	,60906	,60917	,60927	,60938	,60949
407	,60955	,60970	,60981	,60991	,61002	,61013	,61023	,61034	,61045	,61055
408	,61066	,61077	,61087	,61098	,61109	,61119	,61130	,61140	,61151	,61162
409	,61172	,61183	,61194	,61204	,61215	,61225	,61236	,61247	,61257	,61268
410	,61278	,61289	,61300	,61310	,61321	,61331	,61342	,61352	,61363	,61374
411	,61384	,61395	,61405	,61416	,61426	,61437	,61448	,61458	,61469	,61479
412	,61490	,61500	,61511	,61521	,61532	,61542	,61553	,61563	,61574	,61584
413	,61595	,61606	,61616	,61627	,61637	,61648	,61658	,61669	,61679	,61690
414	,61700	,61711	,61721	,61731	,61742	,61752	,61763	,61773	,61784	,61794
415	,61805	,61815	,61826	,61836	,61847	,61857	,61868	,61878	,61888	,61899
416	,61909	,61920	,61930	,61941	,61951	,61961	,61972	,61982	,61993	,62003
417	,62014	,62024	,62034	,62045	,62055	,62066	,62076	,62086	,62097	,62107
418	,62118	,62128	,62138	,62149	,62159	,62170	,62180	,62190	,62201	,62211
419	,62221	,62232	,62242	,62252	,62263	,62273	,62284	,62294	,62304	,62315
420	,62325	,62335	,62346	,62356	,62366	,62377	,62387	,62397	,62408	,62418
421	,62428	,62439	,62449	,62459	,62469	,62480	,62490	,62500	,62511	,62521
422	,62531	,62542	,62552	,62562	,62572	,62583	,62593	,62603	,62613	,62624
423	,62634	,62644	,62655	,62665	,62675	,62685	,62696	,62706	,62716	,62726
424	,62737	,62747	,62757	,62767	,62778	,62788	,62798	,62808	,62818	,62829
425	,62839	,62849	,62859	,62870	,62880	,62890	,62900	,62910	,62921	,62931
426	,62941	,62951	,62961	,62972	,62982	,62992	,63002	,63012	,63022	,63033
427	,63043	,63053	,63063	,63073	,63083	,63094	,63104	,63114	,63124	,63134
428	,63144	,63155	,63165	,63175	,63185	,63195	,63205	,63215	,63225	,63236
429	,63246	,63256	,63266	,63276	,63286	,63296	,63306	,63317	,63327	,63337
430	,63347	,63357	,63367	,63377	,63387	,63397	,63407	,63417	,63428	,63438
431	,63448	,63458	,63468	,63478	,63488	,63498	,63508	,63518	,63528	,63538
432	,63548	,63558	,63568	,63579	,63589	,63599	,63609	,63619	,63629	,63639
433	,63649	,63659	,63669	,63679	,63689	,63699	,63709	,63719	,63729	,63739
434	,63749	,63759	,63769	,63779	,63789	,63799	,63809	,63819	,63829	,63839
435	,63849	,63859	,63869	,63879	,63889	,63899	,63909	,63919	,63929	,63939
436	,63949	,63959	,63969	,63979	,63988	,63998	,64008	,64018	,64028	,64038
437	,64048	,64058	,64068	,64078	,64088	,64098	,64108	,64118	,64128	,64137
438	,64147	,64157	,64167	,64177	,64187	,64197	,64207	,64217	,64227	,64237
439	,64246	,64256	,64266	,64276	,64286	,64296	,64306	,64316	,64326	,64335
440	,64345	,64355	,64365	,64375	,64385	,64395	,64404	,64414	,64424	,64434
441	,64444	,64454	,64464	,64473	,64483	,64493	,64503	,64513	,64523	,64532
442	,64542	,64552	,64562	,64572	,64582	,64591	,64601	,64611	,64621	,64631
443	,64640	,64650	,64660	,64670	,64680	,64689	,64699	,64709	,64719	,64729
444	,64738	,64748	,64758	,64768	,64777	,64787	,64797	,64807	,64816	,64826
445	,64836	,64846	,64856	,64865	,64875	,64885	,64895	,64904	,64914	,64924
446	,64933	,64943	,64953	,64963	,64972	,64982	,64992	,65002	,65011	,65021
447	,65031	,65040	,65050	,65060	,65070	,65079	,65089	,65099	,65108	,65118
448	,65128	,65137	,65147	,65157	,65167	,65176	,65186	,65196	,65205	,65215
449	,65225	,65234	,65244	,65254	,65263	,65273	,65283	,65292	,65302	,65312
450	,65321	,65331	,65341	,65350	,65360	,65369	,65379	,65389	,65398	,65408
451	,65418	,65427	,65437	,65447	,65456	,65466	,65475	,65485	,65495	,65504
452	,65514	,65523	,65533	,65543	,65552	,65562	,65571	,65581	,65591	,65600
453	,65610	,65619	,65629	,65639	,65648	,65658	,65667	,65677	,65686	,65696
454	,65706	,65715	,65725	,65734	,65744	,65753	,65763	,65772	,65782	,65792
455	,65801	,65811	,65820	,65830	,65839	,65849	,65858	,65868	,65877	,65887
456	,65896	,65906	,65916	,65925	,65935	,65944	,65954	,65963	,65973	,65982
457	,65992	,66001	,66011	,66020	,66030	,66039	,66049	,66058	,66068	,66077
458	,66087	,66096	,66106	,66115	,66124	,66134	,66143	,66153	,66162	,66172
459	,66181	,66191	,66200	,66210	,66219	,66229	,66238	,66247	,66257	,66266
N ^o	0	1	2	3	4	5	6	7	8	9

TABLE OF LOGARITHMS. 144. 361

Numbers from 4600 to 5199. Logs. from ,66276 to ,71592.

Nº	0	1	2	3	4	5	6	7	8	9
460	,66276	,66285	,66295	,66304	,66314	,66323	,66332	,66342	,66351	,66361
461	,66370	,66380	,66389	,66398	,66408	,66417	,66427	,66436	,66445	,66455
462	,66464	,66474	,66483	,66492	,66502	,66511	,66521	,66530	,66539	,66549
463	,66558	,66567	,66577	,66586	,66596	,66605	,66614	,66624	,66633	,66642
464	,66652	,66661	,66671	,66680	,66689	,66699	,66708	,66717	,66727	,66736
465	,66745	,66755	,66764	,66773	,66783	,66792	,66801	,66811	,66820	,66829
466	,66839	,66848	,66857	,66867	,66876	,66885	,66894	,66904	,66913	,66922
467	,66932	,66941	,66950	,66960	,66969	,66978	,66987	,66997	,67006	,67015
468	,67025	,67034	,67043	,67052	,67062	,67071	,67080	,67089	,67099	,67108
469	,67117	,67127	,67136	,67145	,67154	,67164	,67173	,67182	,67191	,67201
470	,67210	,67219	,67228	,67237	,67247	,67256	,67265	,67274	,67284	,67293
471	,67302	,67311	,67321	,67330	,67339	,67348	,67357	,67367	,67376	,67385
472	,67394	,67403	,67413	,67422	,67431	,67440	,67449	,67459	,67468	,67477
473	,67486	,67495	,67504	,67514	,67523	,67532	,67541	,67550	,67560	,67569
474	,67578	,67587	,67596	,67605	,67614	,67624	,67633	,67642	,67651	,67660
475	,67669	,67678	,67688	,67697	,67706	,67715	,67724	,67733	,67742	,67752
476	,67761	,67770	,67779	,67788	,67797	,67806	,67815	,67825	,67834	,67843
477	,67852	,67861	,67870	,67879	,67888	,67897	,67906	,67916	,67925	,67934
478	,67943	,67952	,67961	,67970	,67979	,67988	,67997	,68006	,68015	,68024
479	,68034	,68043	,68052	,68061	,68070	,68079	,68088	,68097	,68106	,68115
480	,68124	,68133	,68142	,68151	,68160	,68169	,68178	,68187	,68196	,68205
481	,68215	,68224	,68233	,68242	,68251	,68260	,68269	,68278	,68287	,68296
482	,68305	,68314	,68323	,68332	,68341	,68350	,68359	,68368	,68377	,68386
483	,68395	,68404	,68413	,68422	,68431	,68440	,68449	,68458	,68467	,68476
484	,68485	,68494	,68502	,68511	,68520	,68529	,68538	,68547	,68556	,68565
485	,68574	,68583	,68592	,68601	,68610	,68619	,68628	,68637	,68646	,68655
486	,68664	,68673	,68681	,68690	,68699	,68708	,68717	,68726	,68735	,68744
487	,68753	,68762	,68771	,68780	,68789	,68797	,68806	,68815	,68824	,68833
488	,68842	,68851	,68860	,68869	,68878	,68886	,68895	,68904	,68913	,68922
489	,68931	,68940	,68949	,68958	,68966	,68975	,68984	,68993	,69002	,69011
490	,69020	,69028	,69037	,69046	,69055	,69064	,69073	,69082	,69090	,69099
491	,69108	,69117	,69126	,69135	,69144	,69152	,69161	,69170	,69179	,69188
492	,69197	,69205	,69214	,69223	,69232	,69241	,69249	,69258	,69267	,69276
493	,69285	,69293	,69302	,69311	,69320	,69329	,69338	,69346	,69355	,69364
494	,69373	,69381	,69390	,69399	,69408	,69417	,69425	,69434	,69443	,69452
495	,69461	,69469	,69478	,69487	,69496	,69504	,69513	,69522	,69531	,69539
496	,69548	,69557	,69566	,69574	,69583	,69592	,69601	,69609	,69618	,69627
497	,69636	,69644	,69653	,69662	,69671	,69679	,69688	,69697	,69705	,69714
498	,69723	,69732	,69740	,69749	,69758	,69767	,69775	,69784	,69793	,69801
499	,69810	,69819	,69827	,69836	,69845	,69854	,69862	,69871	,69880	,69888
500	,69897	,69906	,69914	,69923	,69932	,69940	,69949	,69958	,69966	,69975
501	,69984	,69992	,70001	,70010	,70018	,70027	,70036	,70044	,70053	,70062
502	,70070	,70079	,70088	,70096	,70105	,70114	,70122	,70131	,70140	,70148
503	,70157	,70165	,70174	,70183	,70191	,70200	,70209	,70217	,70226	,70234
504	,70243	,70252	,70260	,70269	,70278	,70286	,70295	,70303	,70312	,70321
505	,70329	,70338	,70346	,70355	,70364	,70372	,70381	,70389	,70398	,70406
506	,70415	,70424	,70432	,70441	,70449	,70458	,70467	,70475	,70484	,70492
507	,70501	,70509	,70518	,70526	,70535	,70544	,70552	,70561	,70569	,70578
508	,70586	,70595	,70603	,70612	,70621	,70629	,70638	,70646	,70655	,70663
509	,70672	,70680	,70689	,70697	,70706	,70714	,70723	,70731	,70740	,70748
510	,70757	,70766	,70774	,70783	,70791	,70800	,70808	,70817	,70825	,70834
511	,70842	,70851	,70859	,70868	,70876	,70885	,70893	,70902	,70910	,70919
512	,70927	,70935	,70944	,70952	,70961	,70969	,70978	,70986	,70995	,71003
513	,71012	,71020	,71029	,71037	,71046	,71054	,71062	,71071	,71079	,71088
514	,71096	,71105	,71113	,71122	,71130	,71139	,71147	,71155	,71164	,71172
515	,71181	,71189	,71198	,71206	,71214	,71223	,71231	,71240	,71248	,71257
516	,71265	,71273	,71282	,71290	,71299	,71307	,71315	,71324	,71332	,71341
517	,71349	,71357	,71366	,71374	,71383	,71391	,71399	,71408	,71416	,71425
518	,71433	,71441	,71450	,71458	,71466	,71475	,71483	,71492	,71500	,71508
519	,71517	,71525	,71533	,71542	,71550	,71559	,71567	,71575	,71584	,71592
Nº	0	1	2	3	4	5	6	7	8	9

362 TABLE OF LOGARITHMS. 144.

Numbers from 5200 to 5799. Logs. from ,71600 to ,76335.

N ^o	0	1	2	3	4	5	6	7	8	9
520	,71600	,71609	,71617	,71625	,71634	,71642	,71650	,71659	,71667	,71675
521	,71684	,71692	,71700	,71709	,71717	,71725	,71734	,71742	,71750	,71759
522	,71767	,71775	,71784	,71792	,71800	,71809	,71817	,71825	,71834	,71842
523	,71850	,71858	,71867	,71875	,71883	,71892	,71900	,71908	,71917	,71925
524	,71933	,71941	,71950	,71958	,71966	,71975	,71983	,71991	,71999	,72008
525	,72016	,72024	,72032	,72041	,72049	,72057	,72066	,72074	,72082	,72090
526	,72099	,72107	,72115	,72123	,72132	,72140	,72148	,72156	,72165	,72173
527	,72181	,72189	,72198	,72206	,72214	,72222	,72230	,72239	,72247	,72255
528	,72263	,72272	,72280	,72288	,72296	,72304	,72313	,72321	,72329	,72337
529	,72346	,72354	,72362	,72370	,72378	,72387	,72395	,72403	,72411	,72419
530	,72428	,72436	,72444	,72452	,72460	,72469	,72477	,72485	,72493	,72501
531	,72509	,72518	,72526	,72534	,72542	,72550	,72558	,72567	,72575	,72583
532	,72591	,72599	,72607	,72616	,72624	,72632	,72640	,72648	,72656	,72665
533	,72673	,72681	,72689	,72697	,72705	,72713	,72722	,72730	,72738	,72746
534	,72754	,72762	,72770	,72779	,72787	,72795	,72803	,72811	,72819	,72827
535	,72835	,72843	,72852	,72860	,72868	,72876	,72884	,72892	,72900	,72908
536	,72916	,72925	,72933	,72941	,72949	,72957	,72965	,72973	,72981	,72989
537	,72997	,73006	,73014	,73022	,73030	,73038	,73046	,73054	,73062	,73070
538	,73078	,73086	,73094	,73102	,73111	,73119	,73127	,73135	,73143	,73151
539	,73159	,73167	,73175	,73183	,73191	,73199	,73207	,73215	,73223	,73231
540	,73239	,73247	,73255	,73263	,73272	,73280	,73288	,73296	,73304	,73312
541	,73320	,73328	,73336	,73344	,73352	,73360	,73368	,73376	,73384	,73392
542	,73400	,73408	,73416	,73424	,73432	,73440	,73448	,73456	,73464	,73472
543	,73480	,73488	,73496	,73504	,73512	,73520	,73528	,73536	,73544	,73552
544	,73560	,73568	,73576	,73584	,73592	,73600	,73608	,73616	,73624	,73632
545	,73640	,73648	,73656	,73664	,73672	,73679	,73687	,73695	,73703	,73711
546	,73719	,73727	,73735	,73743	,73751	,73759	,73767	,73775	,73783	,73791
547	,73799	,73807	,73815	,73823	,73830	,73838	,73846	,73854	,73862	,73870
548	,73878	,73886	,73894	,73902	,73910	,73918	,73926	,73933	,73941	,73949
549	,73957	,73965	,73973	,73981	,73989	,73997	,74005	,74013	,74020	,74028
550	,74036	,74044	,74052	,74060	,74068	,74076	,74084	,74092	,74099	,74107
551	,74115	,74123	,74131	,74139	,74147	,74155	,74162	,74170	,74178	,74186
552	,74194	,74202	,74210	,74217	,74225	,74233	,74241	,74249	,74257	,74265
553	,74273	,74280	,74288	,74296	,74304	,74312	,74320	,74327	,74335	,74343
554	,74351	,74359	,74367	,74374	,74382	,74390	,74398	,74406	,74414	,74421
555	,74429	,74437	,74445	,74453	,74461	,74468	,74476	,74484	,74492	,74500
556	,74507	,74515	,74523	,74531	,74539	,74547	,74554	,74562	,74570	,74578
557	,74586	,74593	,74601	,74609	,74617	,74624	,74632	,74640	,74648	,74656
558	,74663	,74671	,74679	,74687	,74695	,74702	,74710	,74718	,74726	,74733
559	,74741	,74749	,74757	,74764	,74772	,74780	,74788	,74796	,74803	,74811
560	,74819	,74827	,74834	,74842	,74850	,74858	,74865	,74873	,74881	,74889
561	,74896	,74904	,74912	,74919	,74927	,74935	,74943	,74950	,74958	,74966
562	,74974	,74981	,74989	,74997	,75005	,75012	,75020	,75028	,75035	,75043
563	,75051	,75059	,75066	,75074	,75082	,75089	,75097	,75105	,75113	,75120
564	,75128	,75136	,75143	,75151	,75159	,75166	,75174	,75182	,75189	,75197
565	,75205	,75213	,75220	,75228	,75236	,75243	,75251	,75259	,75266	,75274
566	,75282	,75289	,75297	,75305	,75312	,75320	,75328	,75335	,75343	,75351
567	,75358	,75366	,75374	,75381	,75389	,75397	,75404	,75412	,75420	,75427
568	,75435	,75442	,75450	,75458	,75465	,75473	,75481	,75488	,75496	,75504
569	,75511	,75519	,75526	,75534	,75542	,75549	,75557	,75565	,75572	,75580
570	,75587	,75595	,75603	,75610	,75618	,75626	,75633	,75641	,75648	,75656
571	,75664	,75671	,75679	,75686	,75694	,75702	,75709	,75717	,75724	,75732
572	,75740	,75747	,75755	,75762	,75770	,75778	,75785	,75793	,75800	,75808
573	,75815	,75823	,75831	,75838	,75846	,75853	,75861	,75868	,75876	,75884
574	,75891	,75899	,75906	,75914	,75921	,75929	,75937	,75944	,75952	,75959
575	,75967	,75974	,75982	,75989	,75997	,76005	,76012	,76020	,76027	,76035
576	,76042	,76050	,76057	,76065	,76072	,76080	,76087	,76095	,76103	,76110
577	,76118	,76125	,76133	,76140	,76148	,76155	,76163	,76170	,76178	,76185
578	,76193	,76200	,76208	,76215	,76223	,76230	,76238	,76245	,76253	,76260
579	,76268	,76275	,76283	,76290	,76298	,76305	,76313	,76320	,76328	,76335
N ^o	0	1	2	3	4	5	6	7	8	9

TABLE of LOGARITHMS. 144. 363

Numbers from 5800 to 6399. Logs. from ,76343 to ,80611.

Nº	0	1	2	3	4	5	6	7	8	9
580	,76343	,76350	,76358	,76365	,76373	,76380	,76388	,76395	,76403	,76410
581	,76418	,76425	,76433	,76440	,76447	,76455	,76462	,76470	,76477	,76485
582	,76492	,76500	,76507	,76515	,76522	,76530	,76537	,76544	,76552	,76559
583	,76567	,76574	,76582	,76589	,76597	,76604	,76612	,76619	,76626	,76634
584	,76641	,76649	,76656	,76664	,76671	,76678	,76686	,76693	,76701	,76708
585	,76716	,76723	,76730	,76738	,76745	,76753	,76760	,76768	,76775	,76782
586	,76790	,76797	,76805	,76812	,76819	,76827	,76834	,76842	,76849	,76856
587	,76864	,76871	,76879	,76886	,76893	,76901	,76908	,76916	,76923	,76930
588	,76938	,76945	,76952	,76960	,76967	,76975	,76982	,76989	,76997	,77004
589	,77012	,77019	,77026	,77034	,77041	,77048	,77056	,77063	,77070	,77078
590	,77085	,77093	,77100	,77107	,77115	,77122	,77129	,77137	,77144	,77151
591	,77159	,77166	,77173	,77181	,77188	,77195	,77203	,77210	,77217	,77225
592	,77232	,77240	,77247	,77254	,77261	,77269	,77276	,77283	,77291	,77298
593	,77305	,77313	,77320	,77327	,77335	,77342	,77349	,77357	,77364	,77371
594	,77379	,77386	,77393	,77401	,77408	,77415	,77422	,77430	,77437	,77444
595	,77452	,77459	,77466	,77474	,77481	,77488	,77495	,77503	,77510	,77517
596	,77525	,77532	,77539	,77547	,77554	,77561	,77568	,77576	,77583	,77590
597	,77597	,77605	,77612	,77619	,77627	,77634	,77641	,77648	,77656	,77663
598	,77670	,77677	,77685	,77692	,77699	,77706	,77714	,77721	,77728	,77735
599	,77743	,77750	,77757	,77764	,77772	,77779	,77786	,77793	,77801	,77808
600	,77815	,77822	,77830	,77837	,77844	,77851	,77859	,77866	,77873	,77880
601	,77887	,77895	,77902	,77909	,77916	,77924	,77931	,77938	,77945	,77952
602	,77960	,77967	,77974	,77981	,77988	,77996	,78003	,78010	,78017	,78025
603	,78032	,78039	,78046	,78053	,78061	,78068	,78075	,78082	,78089	,78096
604	,78104	,78111	,78118	,78125	,78132	,78140	,78147	,78154	,78161	,78168
605	,78176	,78183	,78190	,78197	,78204	,78211	,78219	,78226	,78233	,78240
606	,78247	,78254	,78262	,78269	,78276	,78283	,78290	,78297	,78305	,78312
607	,78319	,78326	,78333	,78340	,78347	,78355	,78362	,78369	,78376	,78383
608	,78390	,78397	,78405	,78412	,78419	,78426	,78433	,78440	,78447	,78455
609	,78462	,78469	,78476	,78483	,78490	,78497	,78504	,78512	,78519	,78526
610	,78533	,78540	,78547	,78554	,78561	,78569	,78576	,78583	,78590	,78597
611	,78604	,78611	,78618	,78625	,78633	,78640	,78647	,78654	,78661	,78668
612	,78675	,78682	,78689	,78696	,78704	,78711	,78718	,78725	,78732	,78739
613	,78746	,78753	,78760	,78767	,78774	,78781	,78789	,78796	,78803	,78810
614	,78817	,78824	,78831	,78838	,78845	,78852	,78859	,78866	,78873	,78880
615	,78888	,78895	,78902	,78909	,78916	,78923	,78930	,78937	,78944	,78951
616	,78958	,78965	,78972	,78979	,78986	,78993	,79000	,79007	,79014	,79021
617	,79029	,79036	,79043	,79050	,79057	,79064	,79071	,79078	,79085	,79092
618	,79099	,79106	,79113	,79120	,79127	,79134	,79141	,79148	,79155	,79162
619	,79169	,79176	,79183	,79190	,79197	,79204	,79211	,79218	,79225	,79232
620	,79239	,79246	,79253	,79260	,79267	,79274	,79281	,79288	,79295	,79302
621	,79309	,79316	,79323	,79330	,79337	,79344	,79351	,79358	,79365	,79372
622	,79379	,79386	,79393	,79400	,79407	,79414	,79421	,79428	,79435	,79442
623	,79449	,79456	,79463	,79470	,79477	,79484	,79491	,79498	,79505	,79511
624	,79518	,79525	,79532	,79539	,79546	,79553	,79560	,79567	,79574	,79581
625	,79588	,79595	,79602	,79609	,79616	,79623	,79630	,79637	,79644	,79650
626	,79657	,79664	,79671	,79678	,79685	,79692	,79699	,79706	,79713	,79720
627	,79727	,79734	,79741	,79748	,79754	,79761	,79768	,79775	,79782	,79789
628	,79796	,79803	,79810	,79817	,79824	,79831	,79837	,79844	,79851	,79858
629	,79865	,79872	,79879	,79886	,79893	,79900	,79906	,79913	,79920	,79927
630	,79934	,79941	,79948	,79955	,79962	,79969	,79975	,79982	,79989	,79996
631	,80003	,80010	,80017	,80024	,80030	,80037	,80044	,80051	,80058	,80065
632	,80072	,80079	,80085	,80092	,80099	,80106	,80113	,80120	,80127	,80134
633	,80140	,80147	,80154	,80161	,80168	,80175	,80182	,80188	,80195	,80202
634	,80209	,80216	,80223	,80229	,80236	,80243	,80250	,80257	,80264	,80271
635	,80277	,80284	,80291	,80298	,80305	,80312	,80318	,80325	,80332	,80339
636	,80346	,80353	,80359	,80366	,80373	,80380	,80387	,80393	,80400	,80407
637	,80414	,80421	,80428	,80434	,80441	,80448	,80455	,80462	,80468	,80475
638	,80482	,80489	,80496	,80502	,80509	,80516	,80523	,80530	,80536	,80543
639	,80550	,80557	,80564	,80570	,80577	,80584	,80591	,80598	,80604	,80611
Nº	0	1	2	3	4	5	6	7	8	9

364 TABLE OF LOGARITHMS. 144.

Numbers from 6400 to 6999. Logs. from ,80618 to ,84504.

N ^o	0	1	2	3	4	5	6	7	8	9
640	,80618	,80625	,80632	,80638	,80645	,80652	,80659	,80665	,80672	,80679
641	,80686	,80691	,80699	,80706	,80713	,80720	,80726	,80733	,80740	,80747
642	,80753	,80760	,80767	,80774	,80781	,80787	,80794	,80801	,80808	,80814
643	,80821	,80828	,80835	,80841	,80848	,80855	,80862	,80868	,80875	,80882
644	,80889	,80895	,80902	,80909	,80916	,80922	,80929	,80936	,80942	,80949
645	,80956	,80963	,80960	,80976	,80983	,80990	,80996	,81003	,81010	,81017
646	,81023	,81030	,81037	,81043	,81050	,81057	,81064	,81070	,81077	,81084
647	,81090	,81097	,81104	,81111	,81117	,81124	,81131	,81137	,81144	,81151
648	,81157	,81164	,81171	,81178	,81184	,81191	,81198	,81204	,81211	,81218
649	,81224	,81231	,81238	,81245	,81251	,81258	,81265	,81271	,81278	,81285
650	,81291	,81298	,81305	,81311	,81318	,81325	,81331	,81338	,81345	,81351
651	,81358	,81365	,81371	,81378	,81385	,81391	,81398	,81405	,81411	,81418
652	,81425	,81431	,81438	,81445	,81451	,81458	,81465	,81471	,81478	,81485
653	,81491	,81498	,81505	,81511	,81518	,81525	,81531	,81538	,81544	,81551
654	,81558	,81564	,81571	,81578	,81584	,81591	,81598	,81604	,81611	,81617
655	,81624	,81631	,81637	,81644	,81651	,81657	,81664	,81671	,81677	,81684
656	,81690	,81697	,81704	,81710	,81717	,81723	,81730	,81737	,81743	,81750
657	,81757	,81763	,81770	,81776	,81783	,81790	,81796	,81803	,81809	,81816
658	,81823	,81829	,81836	,81842	,81849	,81856	,81862	,81869	,81875	,81882
659	,81889	,81895	,81902	,81908	,81915	,81921	,81928	,81935	,81941	,81948
660	,81954	,81961	,81968	,81974	,81981	,81987	,81994	,82000	,82007	,82014
661	,82020	,82027	,82033	,82040	,82046	,82053	,82060	,82066	,82073	,82079
662	,82086	,82092	,82099	,82105	,82112	,82119	,82125	,82132	,82138	,82145
663	,82151	,82158	,82164	,82171	,82178	,82184	,82191	,82197	,82204	,82210
664	,82217	,82223	,82230	,82236	,82243	,82249	,82256	,82263	,82269	,82276
665	,82282	,82289	,82295	,82302	,82308	,82315	,82321	,82328	,82334	,82341
666	,82347	,82354	,82360	,82367	,82373	,82380	,82387	,82393	,82400	,82406
667	,82413	,82419	,82426	,82432	,82439	,82445	,82452	,82458	,82465	,82471
668	,82478	,82484	,82491	,82497	,82504	,82510	,82517	,82523	,82530	,82536
669	,82543	,82549	,82556	,82562	,82569	,82575	,82582	,82588	,82595	,82601
670	,82607	,82614	,82620	,82627	,82633	,82640	,82646	,82653	,82659	,82666
671	,82672	,82679	,82685	,82692	,82698	,82705	,82711	,82718	,82724	,82730
672	,82737	,82743	,82750	,82756	,82763	,82769	,82776	,82782	,82789	,82795
673	,82802	,82808	,82814	,82821	,82827	,82834	,82840	,82847	,82853	,82860
674	,82866	,82872	,82879	,82885	,82892	,82898	,82905	,82911	,82918	,82924
675	,82930	,82937	,82943	,82950	,82956	,82963	,82969	,82975	,82982	,82988
676	,82995	,83001	,83008	,83014	,83020	,83027	,83033	,83040	,83046	,83052
677	,83059	,83065	,83072	,83078	,83085	,83091	,83097	,83104	,83110	,83117
678	,83123	,83129	,83136	,83142	,83149	,83155	,83161	,83168	,83174	,83181
679	,83187	,83193	,83200	,83206	,83213	,83219	,83225	,83232	,83238	,83244
680	,83251	,83257	,83264	,83270	,83276	,83283	,83289	,83296	,83302	,83308
681	,83315	,83321	,83327	,83334	,83340	,83347	,83353	,83359	,83366	,83372
682	,83378	,83385	,83391	,83398	,83404	,83410	,83417	,83423	,83429	,83436
683	,83442	,83448	,83455	,83461	,83467	,83474	,83480	,83487	,83493	,83499
684	,83506	,83512	,83518	,83525	,83531	,83537	,83544	,83550	,83556	,83563
685	,83569	,83575	,83582	,83588	,83594	,83601	,83607	,83613	,83620	,83626
686	,83632	,83639	,83645	,83651	,83658	,83664	,83670	,83677	,83683	,83689
687	,83696	,83702	,83708	,83715	,83721	,83727	,83734	,83740	,83746	,83753
688	,83759	,83765	,83771	,83778	,83784	,83790	,83797	,83803	,83809	,83816
689	,83822	,83828	,83835	,83841	,83847	,83853	,83860	,83866	,83872	,83879
690	,83885	,83891	,83897	,83904	,83910	,83916	,83923	,83929	,83935	,83942
691	,83948	,83954	,83960	,83967	,83973	,83979	,83985	,83992	,83998	,84004
692	,84011	,84017	,84023	,84029	,84036	,84042	,84048	,84055	,84061	,84067
693	,84073	,84079	,84086	,84092	,84098	,84105	,84111	,84117	,84123	,84130
694	,84136	,84142	,84148	,84155	,84161	,84167	,84173	,84180	,84186	,84192
695	,84198	,84205	,84211	,84217	,84223	,84230	,84236	,84242	,84248	,84255
696	,84261	,84267	,84273	,84280	,84286	,84292	,84298	,84305	,84311	,84317
697	,84323	,84330	,84336	,84342	,84348	,84354	,84361	,84367	,84373	,84379
698	,84386	,84392	,84398	,84404	,84410	,84417	,84423	,84429	,84435	,84441
699	,84448	,84454	,84460	,84466	,84473	,84479	,84485	,84491	,84497	,84504
N ^o	0	1	2	3	4	5	6	7	8	9

TABLE of LOGARITHMS. 144. 365

Numbers from 7000 to 7599. Logs. from ,84510 to ,88076.

No	0	1	2	3	4	5	6	7	8	9
700	,84510	,84516	,84522	,84528	,84535	,84541	,84547	,84553	,84559	,84566
701	,84572	,84578	,84584	,84590	,84597	,84603	,84609	,84615	,84621	,84628
702	,84634	,84640	,84646	,84652	,84658	,84665	,84671	,84677	,84683	,84689
703	,84696	,84702	,84708	,84714	,84720	,84726	,84733	,84739	,84745	,84751
704	,84757	,84763	,84770	,84776	,84782	,84788	,84794	,84800	,84807	,84813
705	,84819	,84825	,84831	,84837	,84844	,84850	,84856	,84862	,84868	,84874
706	,84880	,84887	,84893	,84899	,84905	,84911	,84917	,84924	,84930	,84936
707	,84942	,84948	,84954	,84960	,84967	,84973	,84979	,84985	,84991	,84997
708	,85003	,85009	,85016	,85022	,85028	,85034	,85040	,85046	,85052	,85058
709	,85065	,85071	,85077	,85083	,85089	,85095	,85101	,85107	,85114	,85120
710	,85126	,85132	,85138	,85144	,85150	,85156	,85163	,85169	,85175	,85181
711	,85187	,85193	,85199	,85205	,85211	,85217	,85224	,85230	,85236	,85242
712	,85248	,85254	,85260	,85266	,85272	,85278	,85285	,85291	,85297	,85303
713	,85309	,85315	,85321	,85327	,85333	,85339	,85345	,85352	,85358	,85364
714	,85370	,85376	,85382	,85388	,85394	,85400	,85406	,85412	,85418	,85425
715	,85431	,85437	,85443	,85449	,85455	,85461	,85467	,85473	,85479	,85485
716	,85491	,85497	,85503	,85509	,85516	,85522	,85528	,85534	,85540	,85546
717	,85552	,85558	,85564	,85570	,85576	,85582	,85588	,85594	,85600	,85606
718	,85612	,85618	,85625	,85631	,85637	,85643	,85649	,85655	,85661	,85667
719	,85673	,85679	,85685	,85691	,85697	,85703	,85709	,85715	,85721	,85727
720	,85733	,85739	,85745	,85751	,85757	,85763	,85769	,85775	,85781	,85787
721	,85794	,85800	,85806	,85812	,85818	,85824	,85830	,85836	,85842	,85848
722	,85854	,85860	,85866	,85872	,85878	,85884	,85890	,85896	,85902	,85908
723	,85914	,85920	,85926	,85932	,85938	,85944	,85950	,85956	,85962	,85968
724	,85974	,85980	,85986	,85992	,85998	,86004	,86010	,86016	,86022	,86028
725	,86034	,86040	,86046	,86052	,86058	,86064	,86070	,86076	,86082	,86088
726	,86094	,86100	,86106	,86112	,86118	,86124	,86130	,86136	,86141	,86147
727	,86153	,86159	,86165	,86171	,86177	,86183	,86189	,86195	,86201	,86207
728	,86213	,86219	,86225	,86231	,86237	,86243	,86249	,86255	,86261	,86267
729	,86273	,86279	,86285	,86291	,86297	,86303	,86308	,86314	,86320	,86326
730	,86332	,86338	,86344	,86350	,86356	,86362	,86368	,86374	,86380	,86386
731	,86392	,86398	,86404	,86410	,86415	,86421	,86427	,86433	,86439	,86445
732	,86451	,86457	,86463	,86469	,86475	,86481	,86487	,86493	,86499	,86504
733	,86510	,86516	,86522	,86528	,86534	,86540	,86546	,86552	,86558	,86564
734	,86570	,86576	,86581	,86587	,86593	,86599	,86605	,86611	,86617	,86623
735	,86629	,86635	,86641	,86646	,86652	,86658	,86664	,86670	,86676	,86682
736	,86688	,86694	,86700	,86705	,86711	,86717	,86723	,86729	,86735	,86741
737	,86747	,86753	,86759	,86764	,86770	,86776	,86782	,86788	,86794	,86800
738	,86806	,86812	,86817	,86823	,86829	,86835	,86841	,86847	,86853	,86859
739	,86864	,86870	,86876	,86882	,86888	,86894	,86900	,86906	,86911	,86917
740	,86923	,86929	,86935	,86941	,86947	,86953	,86958	,86964	,86970	,86976
741	,86982	,86988	,86994	,86999	,87005	,87011	,87017	,87023	,87029	,87035
742	,87040	,87046	,87052	,87058	,87064	,87070	,87075	,87081	,87087	,87093
743	,87099	,87105	,87111	,87116	,87122	,87128	,87134	,87140	,87146	,87151
744	,87157	,87163	,87169	,87175	,87181	,87186	,87192	,87198	,87204	,87210
745	,87216	,87221	,87227	,87233	,87239	,87245	,87251	,87256	,87262	,87268
746	,87274	,87280	,87286	,87291	,87297	,87303	,87309	,87315	,87320	,87326
747	,87332	,87338	,87344	,87349	,87355	,87361	,87367	,87373	,87379	,87384
748	,87390	,87396	,87402	,87408	,87413	,87419	,87425	,87431	,87437	,87442
749	,87448	,87454	,87460	,87466	,87471	,87477	,87483	,87489	,87495	,87500
750	,87506	,87512	,87518	,87523	,87529	,87535	,87541	,87547	,87552	,87558
751	,87564	,87570	,87576	,87581	,87587	,87593	,87599	,87604	,87610	,87616
752	,87622	,87628	,87633	,87639	,87645	,87651	,87656	,87662	,87668	,87674
753	,87679	,87685	,87691	,87697	,87703	,87708	,87714	,87720	,87726	,87731
754	,87737	,87743	,87749	,87754	,87760	,87766	,87772	,87777	,87783	,87789
755	,87795	,87800	,87806	,87812	,87818	,87823	,87829	,87835	,87841	,87846
756	,87852	,87858	,87864	,87869	,87875	,87881	,87887	,87892	,87898	,87904
757	,87910	,87915	,87921	,87927	,87933	,87938	,87944	,87950	,87955	,87961
758	,87967	,87973	,87978	,87984	,87990	,87996	,88001	,88007	,88013	,88018
759	,88024	,88030	,88036	,88041	,88047	,88053	,88058	,88064	,88070	,88076
No	0	1	2	3	4	5	6	7	8	9

366 TABLE OF LOGARITHMS. 144.

Numbers from 7600 to 8199. Logs. from ,88081 to ,91376.

Nº	0	1	2	3	4	5	6	7	8	9
760	,88081	,88087	,88093	,88098	,88104	,88110	,88116	,88121	,88127	,88133
761	,88138	,88144	,88150	,88156	,88161	,88167	,88173	,88178	,88184	,88190
762	,88195	,88201	,88207	,88213	,88218	,88224	,88230	,88235	,88241	,88247
763	,88252	,88258	,88264	,88270	,88275	,88281	,88287	,88292	,88298	,88304
764	,88309	,88315	,88321	,88326	,88332	,88338	,88343	,88349	,88355	,88360
765	,88366	,88372	,88377	,88383	,88389	,88395	,88400	,88406	,88412	,88417
766	,88423	,88429	,88434	,88440	,88446	,88451	,88457	,88463	,88468	,88474
767	,88480	,88485	,88491	,88497	,88502	,88508	,88513	,88519	,88525	,88530
768	,88536	,88542	,88547	,88553	,88559	,88564	,88570	,88576	,88581	,88587
769	,88593	,88598	,88604	,88610	,88615	,88621	,88627	,88632	,88638	,88643
770	,88649	,88655	,88660	,88666	,88672	,88677	,88683	,88689	,88694	,88700
771	,88705	,88711	,88717	,88722	,88728	,88734	,88739	,88745	,88750	,88756
772	,88762	,88767	,88773	,88779	,88784	,88790	,88795	,88801	,88807	,88812
773	,88818	,88824	,88829	,88835	,88840	,88846	,88852	,88857	,88863	,88868
774	,88874	,88880	,88885	,88891	,88897	,88902	,88908	,88913	,88919	,88925
775	,88930	,88936	,88941	,88947	,88953	,88958	,88964	,88969	,88975	,88981
776	,88986	,88992	,88997	,89003	,89009	,89014	,89020	,89025	,89031	,89037
777	,89042	,89048	,89053	,89059	,89064	,89070	,89076	,89081	,89087	,89092
778	,89098	,89104	,89109	,89115	,89120	,89126	,89131	,89137	,89143	,89148
779	,89154	,89159	,89165	,89170	,89176	,89182	,89187	,89193	,89198	,89204
780	,89209	,89215	,89221	,89226	,89232	,89237	,89243	,89248	,89254	,89260
781	,89265	,89271	,89276	,89282	,89287	,89293	,89298	,89304	,89310	,89315
782	,89321	,89326	,89332	,89337	,89343	,89348	,89354	,89360	,89365	,89371
783	,89376	,89382	,89387	,89393	,89398	,89404	,89409	,89415	,89421	,89426
784	,89432	,89437	,89443	,89448	,89454	,89459	,89465	,89470	,89476	,89481
785	,89487	,89492	,89498	,89504	,89509	,89515	,89520	,89526	,89531	,89537
786	,89542	,89548	,89553	,89559	,89564	,89570	,89575	,89581	,89586	,89592
787	,89597	,89603	,89609	,89614	,89620	,89625	,89631	,89636	,89642	,89647
788	,89653	,89658	,89664	,89669	,89675	,89680	,89686	,89691	,89697	,89702
789	,89708	,89713	,89719	,89724	,89730	,89735	,89741	,89746	,89752	,89757
790	,89763	,89768	,89774	,89779	,89785	,89790	,89796	,89801	,89807	,89812
791	,89818	,89823	,89829	,89834	,89840	,89845	,89851	,89856	,89862	,89867
792	,89873	,89878	,89883	,89889	,89894	,89900	,89905	,89911	,89916	,89922
793	,89927	,89933	,89938	,89944	,89949	,89955	,89960	,89966	,89971	,89977
794	,89982	,89988	,89993	,89998	,90004	,90009	,90015	,90020	,90026	,90031
795	,90037	,90042	,90048	,90053	,90059	,90064	,90069	,90075	,90080	,90086
796	,90091	,90097	,90102	,90108	,90113	,90119	,90124	,90129	,90135	,90140
797	,90146	,90151	,90157	,90162	,90168	,90173	,90179	,90184	,90189	,90195
798	,90200	,90206	,90211	,90217	,90222	,90227	,90233	,90238	,90244	,90249
799	,90255	,90260	,90266	,90271	,90276	,90282	,90287	,90293	,90298	,90304
800	,90309	,90314	,90320	,90325	,90331	,90336	,90342	,90347	,90352	,90358
801	,90363	,90369	,90374	,90380	,90385	,90390	,90396	,90401	,90407	,90412
802	,90417	,90423	,90428	,90434	,90439	,90444	,90450	,90455	,90461	,90466
803	,90472	,90477	,90482	,90488	,90493	,90499	,90504	,90509	,90515	,90520
804	,90526	,90531	,90536	,90542	,90547	,90553	,90558	,90563	,90569	,90574
805	,90580	,90585	,90590	,90596	,90601	,90607	,90612	,90617	,90623	,90628
806	,90633	,90639	,90644	,90650	,90655	,90660	,90666	,90671	,90677	,90682
807	,90687	,90693	,90698	,90703	,90709	,90714	,90720	,90725	,90730	,90736
808	,90741	,90747	,90752	,90757	,90763	,90768	,90773	,90779	,90784	,90789
809	,90795	,90800	,90806	,90811	,90816	,90822	,90827	,90832	,90838	,90843
810	,90848	,90854	,90859	,90865	,90870	,90875	,90881	,90886	,90891	,90897
811	,90902	,90907	,90913	,90918	,90923	,90929	,90934	,90940	,90945	,90950
812	,90956	,90961	,90966	,90972	,90977	,90982	,90988	,90993	,90998	,91004
813	,91009	,91014	,91020	,91025	,91030	,91036	,91041	,91046	,91052	,91057
814	,91062	,91068	,91073	,91078	,91084	,91089	,91094	,91100	,91105	,91110
815	,91116	,91121	,91126	,91132	,91137	,91142	,91148	,91153	,91158	,91164
816	,91169	,91174	,91180	,91185	,91190	,91196	,91201	,91206	,91212	,91217
817	,91222	,91228	,91233	,91238	,91243	,91249	,91254	,91259	,91265	,91270
818	,91275	,91281	,91286	,91291	,91297	,91302	,91307	,91312	,91318	,91323
819	,91328	,91334	,91339	,91344	,91350	,91355	,91360	,91365	,91371	,91376
Nº	0	1	2	3	4	5	6	7	8	9

TABLE OF LOGARITHMS. 144. 367

Numbers from 8200 to 8799. Logs. from ,91381 to ,94443.

Nº	0	1	2	3	4	5	6	7	8	9
820	,91381	,91387	,91392	,91397	,91403	,91408	,91413	,91418	,91424	,91429
821	,91434	,91440	,91445	,91450	,91455	,91461	,91466	,91471	,91477	,91482
822	,91487	,91492	,91498	,91503	,91508	,91514	,91519	,91524	,91529	,91535
823	,91540	,91545	,91551	,91556	,91561	,91566	,91572	,91577	,91582	,91587
824	,91593	,91598	,91603	,91609	,91614	,91619	,91624	,91630	,91635	,91640
825	,91645	,91651	,91656	,91661	,91666	,91672	,91677	,91682	,91687	,91693
826	,91698	,91703	,91709	,91714	,91719	,91724	,91730	,91735	,91740	,91745
827	,91751	,91756	,91761	,91766	,91772	,91777	,91782	,91787	,91793	,91798
828	,91803	,91808	,91814	,91819	,91824	,91829	,91834	,91840	,91845	,91850
829	,91855	,91861	,91866	,91871	,91876	,91882	,91887	,91892	,91897	,91903
830	,91908	,91913	,91918	,91923	,91929	,91934	,91939	,91944	,91950	,91955
831	,91960	,91965	,91971	,91976	,91981	,91986	,91991	,91997	,92002	,92007
832	,92012	,92018	,92023	,92028	,92033	,92038	,92044	,92049	,92054	,92059
833	,92064	,92070	,92075	,92080	,92085	,92091	,92096	,92101	,92106	,92111
834	,92117	,92122	,92127	,92132	,92137	,92143	,92148	,92153	,92158	,92163
835	,92169	,92174	,92179	,92184	,92189	,92195	,92200	,92205	,92210	,92215
836	,92221	,92226	,92231	,92236	,92241	,92247	,92252	,92257	,92262	,92267
837	,92273	,92278	,92283	,92288	,92293	,92298	,92304	,92309	,92314	,92319
838	,92324	,92330	,92335	,92340	,92345	,92350	,92355	,92361	,92366	,92371
839	,92376	,92381	,92387	,92392	,92397	,92402	,92407	,92412	,92418	,92423
840	,92428	,92433	,92438	,92443	,92449	,92454	,92459	,92464	,92469	,92474
841	,92480	,92485	,92490	,92495	,92500	,92505	,92511	,92516	,92521	,92526
842	,92531	,92536	,92542	,92547	,92552	,92557	,92562	,92567	,92572	,92578
843	,92583	,92588	,92593	,92598	,92603	,92609	,92614	,92619	,92624	,92629
844	,92634	,92639	,92645	,92650	,92655	,92660	,92665	,92670	,92675	,92681
845	,92686	,92691	,92696	,92701	,92706	,92711	,92716	,92722	,92727	,92732
846	,92737	,92742	,92747	,92752	,92758	,92763	,92768	,92773	,92778	,92783
847	,92788	,92793	,92799	,92804	,92809	,92814	,92819	,92824	,92829	,92834
848	,92840	,92845	,92850	,92855	,92860	,92865	,92870	,92875	,92881	,92886
849	,92891	,92896	,92901	,92906	,92911	,92916	,92921	,92927	,92932	,92937
850	,92942	,92947	,92952	,92957	,92962	,92967	,92973	,92978	,92983	,92988
851	,92993	,92998	,93003	,93008	,93013	,93018	,93024	,93029	,93034	,93039
852	,93044	,93049	,93054	,93059	,93064	,93069	,93075	,93080	,93085	,93090
853	,93095	,93100	,93105	,93110	,93115	,93120	,93125	,93131	,93136	,93141
854	,93146	,93151	,93156	,93161	,93166	,93171	,93176	,93181	,93186	,93192
855	,93197	,93202	,93207	,93212	,93217	,93222	,93227	,93232	,93237	,93242
856	,93247	,93252	,93258	,93263	,93268	,93273	,93278	,93283	,93288	,93293
857	,93298	,93303	,93308	,93313	,93318	,93323	,93328	,93334	,93339	,93344
858	,93349	,93354	,93359	,93364	,93369	,93374	,93379	,93384	,93389	,93394
859	,93399	,93404	,93409	,93414	,93420	,93425	,93430	,93435	,93440	,93445
860	,93450	,93455	,93460	,93465	,93470	,93475	,93480	,93485	,93490	,93495
861	,93500	,93505	,93510	,93515	,93520	,93526	,93531	,93536	,93541	,93546
862	,93551	,93556	,93561	,93566	,93571	,93576	,93581	,93586	,93591	,93596
863	,93601	,93606	,93611	,93616	,93621	,93626	,93631	,93636	,93641	,93646
864	,93651	,93656	,93661	,93666	,93671	,93676	,93682	,93687	,93692	,93697
865	,93702	,93707	,93712	,93717	,93722	,93727	,93732	,93737	,93742	,93747
866	,93752	,93757	,93762	,93767	,93772	,93777	,93782	,93787	,93792	,93797
867	,93802	,93807	,93812	,93817	,93822	,93827	,93832	,93837	,93842	,93847
868	,93852	,93857	,93862	,93867	,93872	,93877	,93882	,93887	,93892	,93897
869	,93902	,93907	,93912	,93917	,93922	,93927	,93932	,93937	,93942	,93947
870	,93952	,93957	,93962	,93967	,93972	,93977	,93982	,93987	,93992	,93997
871	,94002	,94007	,94012	,94017	,94022	,94027	,94032	,94037	,94042	,94047
872	,94052	,94057	,94062	,94067	,94072	,94077	,94082	,94086	,94091	,94096
873	,94101	,94106	,94111	,94116	,94121	,94126	,94131	,94136	,94141	,94146
874	,94151	,94156	,94161	,94166	,94171	,94176	,94181	,94186	,94191	,94196
875	,94201	,94206	,94211	,94216	,94221	,94226	,94231	,94236	,94240	,94245
876	,94250	,94255	,94260	,94265	,94270	,94275	,94280	,94285	,94290	,94295
877	,94300	,94305	,94310	,94315	,94320	,94325	,94330	,94335	,94340	,94344
878	,94349	,94354	,94359	,94364	,94369	,94374	,94379	,94384	,94389	,94394
879	,94399	,94404	,94409	,94414	,94419	,94424	,94429	,94433	,94438	,94443
Nº	0	1	2	3	4	5	6	7	8	9

368 TABLE OF LOGARITHMS. 144.

Numbers from 8800 to 9399. Logs. from ,94448 to ,97308.

Nº	0	1	2	3	4	5	6	7	8	9
880	,94448	,94453	,94458	,94463	,94468	,94473	,94478	,94483	,94488	,94493
881	,94498	,94503	,94507	,94512	,94517	,94522	,94527	,94532	,94537	,94542
882	,94547	,94552	,94557	,94562	,94567	,94571	,94576	,94581	,94586	,94591
883	,94596	,94601	,94606	,94611	,94616	,94621	,94626	,94630	,94635	,94640
884	,94645	,94650	,94655	,94660	,94665	,94670	,94675	,94680	,94685	,94690
885	,94694	,94699	,94704	,94709	,94714	,94719	,94724	,94729	,94734	,94738
886	,94743	,94748	,94753	,94758	,94763	,94768	,94773	,94778	,94783	,94787
887	,94792	,94797	,94802	,94807	,94812	,94817	,94822	,94827	,94832	,94836
888	,94841	,94846	,94851	,94856	,94861	,94866	,94871	,94876	,94880	,94885
889	,94890	,94895	,94900	,94905	,94910	,94915	,94919	,94924	,94929	,94934
890	,94939	,94944	,94949	,94954	,94959	,94963	,94968	,94973	,94978	,94983
891	,94988	,94993	,94998	,95002	,95007	,95012	,95017	,95022	,95027	,95032
892	,95036	,95041	,95046	,95051	,95056	,95061	,95066	,95071	,95075	,95080
893	,95085	,95090	,95095	,95100	,95105	,95109	,95114	,95119	,95124	,95129
894	,95134	,95139	,95143	,95148	,95153	,95158	,95163	,95168	,95173	,95177
895	,95182	,95187	,95192	,95197	,95202	,95207	,95211	,95216	,95221	,95226
896	,95231	,95236	,95240	,95245	,95250	,95255	,95260	,95265	,95270	,95274
897	,95279	,95284	,95289	,95294	,95299	,95303	,95308	,95313	,95318	,95323
898	,95328	,95332	,95337	,95342	,95347	,95352	,95357	,95361	,95366	,95371
899	,95376	,95381	,95386	,95390	,95395	,95400	,95405	,95410	,95415	,95419
900	,95424	,95429	,95434	,95439	,95444	,95448	,95453	,95458	,95463	,95468
901	,95472	,95477	,95482	,95487	,95492	,95497	,95501	,95506	,95511	,95516
902	,95521	,95525	,95530	,95535	,95540	,95545	,95550	,95554	,95559	,95564
903	,95569	,95574	,95578	,95583	,95588	,95593	,95598	,95602	,95607	,95612
904	,95617	,95622	,95626	,95631	,95636	,95641	,95646	,95650	,95655	,95660
905	,95665	,95670	,95674	,95679	,95684	,95689	,95694	,95698	,95703	,95708
906	,95713	,95718	,95722	,95727	,95732	,95737	,95742	,95746	,95751	,95756
907	,95761	,95766	,95770	,95775	,95780	,95785	,95789	,95794	,95799	,95804
908	,95809	,95813	,95818	,95823	,95828	,95832	,95837	,95842	,95847	,95852
909	,95856	,95861	,95866	,95871	,95875	,95880	,95885	,95890	,95895	,95899
910	,95904	,95909	,95914	,95918	,95923	,95928	,95933	,95938	,95942	,95947
911	,95952	,95957	,95961	,95966	,95971	,95976	,95980	,95985	,95990	,95995
912	,95999	,96004	,96009	,96014	,96019	,96023	,96028	,96033	,96038	,96042
913	,96047	,96052	,96057	,96061	,96066	,96071	,96076	,96080	,96085	,96090
914	,96095	,96099	,96104	,96109	,96114	,96118	,96123	,96128	,96133	,96137
915	,96142	,96147	,96152	,96156	,96161	,96166	,96171	,96175	,96180	,96185
916	,96190	,96194	,96199	,96204	,96209	,96213	,96218	,96223	,96227	,96232
917	,96237	,96242	,96246	,96251	,96256	,96261	,96265	,96270	,96275	,96280
918	,96284	,96289	,96294	,96298	,96303	,96308	,96313	,96317	,96322	,96327
919	,96332	,96336	,96341	,96346	,96350	,96355	,96360	,96365	,96369	,96374
920	,96379	,96383	,96388	,96393	,96398	,96402	,96407	,96412	,96417	,96421
921	,96426	,96431	,96435	,96440	,96445	,96450	,96454	,96459	,96464	,96468
922	,96473	,96478	,96483	,96487	,96492	,96497	,96501	,96506	,96511	,96515
923	,96520	,96525	,96530	,96534	,96539	,96544	,96548	,96553	,96558	,96562
924	,96567	,96572	,96577	,96581	,96586	,96591	,96595	,96600	,96605	,96609
925	,96614	,96619	,96624	,96628	,96633	,96638	,96642	,96647	,96652	,96656
926	,96661	,96666	,96672	,96675	,96680	,96685	,96689	,96694	,96699	,96703
927	,96708	,96713	,96717	,96722	,96727	,96731	,96736	,96741	,96745	,96750
928	,96755	,96759	,96764	,96769	,96774	,96778	,96783	,96788	,96793	,96797
929	,96802	,96806	,96811	,96816	,96820	,96825	,96830	,96834	,96839	,96844
930	,96848	,96853	,96858	,96862	,96867	,96872	,96876	,96881	,96886	,96890
931	,96895	,96900	,96904	,96909	,96914	,96918	,96923	,96928	,96932	,96937
932	,96942	,96946	,96951	,96956	,96960	,96965	,96970	,96974	,96979	,96984
933	,96988	,96993	,96997	,97002	,97007	,97011	,97016	,97021	,97025	,97030
934	,97035	,97039	,97044	,97049	,97053	,97058	,97063	,97067	,97072	,97077
935	,97081	,97086	,97090	,97095	,97100	,97104	,97109	,97114	,97118	,97123
936	,97128	,97132	,97137	,97141	,97146	,97151	,97155	,97160	,97165	,97169
937	,97174	,97179	,97183	,97188	,97192	,97197	,97202	,97206	,97211	,97216
938	,97220	,97225	,97230	,97234	,97239	,97243	,97248	,97253	,97257	,97262
939	,97267	,97271	,97276	,97280	,97285	,97290	,97294	,97299	,97304	,97308
Nº	0	1	2	3	4	5	6	7	8	9

TABLE of LOGARITHMS. 144. 369

Numbers from 9400 to 9999. Logs. from ,97313 to ,99996.

Nº	0	1	2	3	4	5	6	7	8	9
940	,97313	,97317	,97322	,97327	,97331	,97336	,97340	,97345	,97350	,97354
941	,97359	,97364	,97368	,97373	,97377	,97382	,97387	,97391	,97396	,97400
942	,97405	,97410	,97414	,97419	,97424	,97428	,97433	,97437	,97442	,97447
943	,97451	,97456	,97460	,97465	,97470	,97474	,97479	,97483	,97488	,97493
944	,97497	,97502	,97506	,97511	,97516	,97520	,97525	,97529	,97534	,97539
945	,97543	,97548	,97552	,97557	,97562	,97566	,97571	,97575	,97580	,97585
946	,97589	,97594	,97598	,97603	,97607	,97612	,97617	,97621	,97626	,97630
947	,97635	,97640	,97644	,97649	,97653	,97658	,97663	,97667	,97672	,97676
948	,97681	,97685	,97690	,97695	,97699	,97704	,97708	,97713	,97717	,97722
949	,97727	,97731	,97736	,97740	,97745	,97749	,97754	,97759	,97763	,97768
950	,97772	,97777	,97781	,97786	,97791	,97795	,97800	,97804	,97809	,97813
951	,97818	,97823	,97827	,97832	,97836	,97841	,97845	,97850	,97855	,97859
952	,97864	,97868	,97873	,97877	,97882	,97886	,97891	,97896	,97900	,97905
953	,97909	,97914	,97918	,97923	,97928	,97932	,97937	,97941	,97946	,97950
954	,97955	,97959	,97964	,97968	,97973	,97978	,97982	,97987	,97991	,97996
955	,98000	,98005	,98009	,98014	,98019	,98023	,98028	,98032	,98037	,98041
956	,98046	,98050	,98055	,98059	,98064	,98068	,98073	,98078	,98082	,98087
957	,98091	,98096	,98100	,98105	,98109	,98114	,98118	,98123	,98127	,98132
958	,98137	,98141	,98146	,98150	,98155	,98159	,98164	,98168	,98173	,98177
959	,98182	,98186	,98191	,98195	,98200	,98204	,98209	,98214	,98218	,98223
960	,98227	,98232	,98236	,98241	,98245	,98250	,98254	,98259	,98263	,98268
961	,98272	,98277	,98281	,98286	,98290	,98295	,98299	,98304	,98308	,98313
962	,98318	,98322	,98327	,98331	,98336	,98340	,98345	,98349	,98354	,98358
963	,98363	,98367	,98372	,98376	,98381	,98385	,98390	,98394	,98399	,98403
964	,98408	,98412	,98417	,98421	,98426	,98430	,98435	,98439	,98444	,98448
965	,98453	,98457	,98462	,98466	,98471	,98475	,98480	,98484	,98489	,98493
966	,98498	,98502	,98507	,98511	,98516	,98520	,98525	,98529	,98534	,98538
967	,98543	,98547	,98552	,98556	,98561	,98565	,98570	,98574	,98579	,98583
968	,98588	,98592	,98597	,98601	,98605	,98610	,98614	,98619	,98623	,98628
969	,98632	,98637	,98641	,98646	,98650	,98655	,98659	,98664	,98668	,98673
970	,98677	,98682	,98686	,98691	,98695	,98700	,98704	,98708	,98713	,98717
971	,98722	,98726	,98731	,98735	,98740	,98744	,98749	,98753	,98758	,98762
972	,98767	,98771	,98776	,98780	,98784	,98789	,98793	,98798	,98802	,98807
973	,98811	,98816	,98820	,98825	,98829	,98834	,98838	,98843	,98847	,98851
974	,98856	,98860	,98865	,98869	,98874	,98878	,98883	,98887	,98892	,98896
975	,98900	,98905	,98909	,98914	,98918	,98923	,98927	,98932	,98936	,98941
976	,98945	,98949	,98954	,98958	,98963	,98967	,98972	,98976	,98981	,98985
977	,98989	,98994	,98998	,99003	,99007	,99012	,99016	,99021	,99025	,99029
978	,99034	,99038	,99043	,99047	,99052	,99056	,99061	,99065	,99069	,99074
979	,99078	,99083	,99087	,99092	,99096	,99100	,99105	,99109	,99114	,99118
980	,99123	,99127	,99131	,99136	,99140	,99145	,99149	,99154	,99158	,99162
981	,99167	,99171	,99176	,99180	,99185	,99189	,99193	,99198	,99202	,99207
982	,99211	,99216	,99220	,99224	,99229	,99233	,99238	,99242	,99247	,99251
983	,99255	,99260	,99264	,99269	,99273	,99277	,99282	,99286	,99291	,99295
984	,99300	,99304	,99308	,99313	,99317	,99322	,99326	,99330	,99335	,99339
985	,99344	,99348	,99352	,99357	,99361	,99366	,99370	,99374	,99379	,99383
986	,99388	,99392	,99396	,99401	,99405	,99410	,99414	,99419	,99423	,99427
987	,99432	,99436	,99441	,99445	,99449	,99454	,99458	,99463	,99467	,99471
988	,99476	,99480	,99484	,99489	,99493	,99498	,99502	,99506	,99511	,99515
989	,99520	,99524	,99528	,99533	,99537	,99542	,99546	,99550	,99555	,99559
990	,99564	,99568	,99572	,99577	,99581	,99585	,99590	,99594	,99599	,99603
991	,99607	,99612	,99616	,99621	,99625	,99629	,99634	,99638	,99642	,99647
992	,99651	,99656	,99660	,99664	,99669	,99673	,99677	,99682	,99686	,99691
993	,99695	,99699	,99704	,99708	,99712	,99717	,99721	,99726	,99730	,99734
994	,99739	,99743	,99747	,99752	,99756	,99760	,99765	,99769	,99774	,99778
995	,99782	,99787	,99791	,99795	,99800	,99804	,99808	,99813	,99817	,99822
996	,99826	,99830	,99835	,99839	,99843	,99848	,99852	,99856	,99861	,99865
997	,99870	,99874	,99878	,99883	,99887	,99891	,99896	,99900	,99904	,99909
998	,99913	,99917	,99922	,99926	,99930	,99935	,99939	,99943	,99948	,99952
999	,99957	,99961	,99965	,99970	,99974	,99978	,99983	,99987	,99991	,99996
Nº	0	1	2	3	4	5	6	7	8	9

370 TABLE OF SINES AND TANGENTS. 145.

0 Degree.					1 Degree.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	0,00000	1,00000	0,00000	Infinite.	60	0,824186	9,99993	8,24192	11,75808
1	6,46373	9,99999	6,46373	13,53627	59	18,24903	9,99993	8,24910	11,75090
2	6,76476	9,99999	6,76476	13,23524	58	28,25609	9,99993	8,25616	11,74384
3	6,94085	9,99999	6,94085	13,05915	57	38,26304	9,99993	8,26312	11,73688
4	7,06579	9,99999	7,06579	12,93421	56	48,26988	9,99992	8,26996	11,73004
5	7,16270	9,99999	7,16270	12,83730	55	58,27661	9,99992	8,27669	11,72331
6	7,24188	9,99999	7,24188	12,75812	54	68,28324	9,99992	8,28332	11,71668
7	7,30882	9,99999	7,30882	12,69118	53	78,28977	9,99992	8,28986	11,71014
8	7,36682	9,99999	7,36682	12,63318	52	88,29621	9,99991	8,29629	11,70371
9	7,41797	9,99999	7,41797	12,58203	51	98,3025	9,99991	8,30263	11,69737
10	7,46373	9,99999	7,46373	12,53627	50	108,30879	9,99991	8,30888	11,69112
11	7,50512	9,99999	7,50512	12,49488	49	118,31495	9,99991	8,31505	11,68495
12	7,54291	9,99999	7,54291	12,45794	48	128,32103	9,99990	8,32112	11,67888
13	7,57767	9,99999	7,57767	12,42233	47	138,32702	9,99990	8,32711	11,67289
14	7,60985	9,99999	7,60985	12,39014	46	148,33292	9,99990	8,33302	11,66698
15	7,63982	9,99999	7,63982	12,36018	45	158,33875	9,99990	8,33886	11,66114
16	7,66784	9,99999	7,66784	12,33215	44	168,34450	9,99989	8,34461	11,65539
17	7,69417	9,99999	7,69417	12,30582	43	178,35018	9,99989	8,35029	11,64971
18	7,71900	9,99999	7,71900	12,28100	42	188,35578	9,99989	8,35590	11,64410
19	7,74248	9,99999	7,74248	12,25752	41	198,36131	9,99989	8,36143	11,63857
20	7,76475	9,99999	7,76475	12,23524	40	208,36678	9,99988	8,36689	11,63311
21	7,78594	9,99999	7,78594	12,21405	39	218,37217	9,99988	8,37229	11,62771
22	7,80615	9,99999	7,80615	12,19385	38	228,37750	9,99988	8,37762	11,62238
23	7,82545	9,99999	7,82545	12,17454	37	238,38276	9,99987	8,38289	11,61711
24	7,84393	9,99999	7,84393	12,15606	36	248,38796	9,99987	8,38809	11,61191
25	7,86166	9,99999	7,86166	12,13833	35	258,39310	9,99987	8,39323	11,60677
26	7,87870	9,99999	7,87870	12,12120	34	268,39818	9,99986	8,39832	11,60168
27	7,89509	9,99999	7,89509	12,10490	33	278,40320	9,99986	8,40334	11,59666
28	7,91088	9,99999	7,91088	12,08911	32	288,40816	9,99986	8,40830	11,59170
29	7,92612	9,99998	7,92612	12,0738	31	298,41307	9,99985	8,41321	11,58679
30	7,94084	9,99998	7,94084	12,05914	30	308,41792	9,99985	8,41807	11,58193
31	7,95508	9,99998	7,95508	12,04490	29	318,42272	9,99985	8,42287	11,57713
32	7,96887	9,99998	7,96887	12,03111	28	328,42746	9,99984	8,42762	11,57238
33	7,98225	9,99998	7,98225	12,01775	27	338,43216	9,99984	8,43231	11,56768
34	7,99520	9,99998	7,99520	12,00478	26	348,43680	9,99984	8,43696	11,56304
35	8,00779	9,99998	8,00779	11,99219	25	358,44139	9,99983	8,44156	11,55844
36	8,02002	9,99998	8,02002	11,97996	24	368,44594	9,99983	8,44611	11,55389
37	8,03192	9,99997	8,03192	11,96806	23	378,45044	9,99983	8,45061	11,54939
38	8,04350	9,99997	8,04350	11,95647	22	388,45489	9,99982	8,45507	11,54493
39	8,05478	9,99997	8,05478	11,94519	21	398,45930	9,99982	8,45948	11,54052
40	8,06578	9,99997	8,06578	11,93419	20	408,46366	9,99982	8,46385	11,53615
41	8,07650	9,99997	8,07650	11,92347	19	418,46798	9,99981	8,46817	11,53183
42	8,08696	9,99997	8,08696	11,91300	18	428,47226	9,99981	8,47245	11,52755
43	8,09718	9,99997	8,09718	11,90278	17	438,47650	9,99980	8,47669	11,52331
44	8,10717	9,99996	8,10717	11,89280	16	448,48069	9,99980	8,48089	11,51911
45	8,11693	9,99996	8,11693	11,88304	15	458,48485	9,99980	8,48505	11,51495
46	8,12647	9,99996	8,12647	11,87349	14	468,48896	9,99979	8,48917	11,51083
47	8,13581	9,99996	8,13581	11,86415	13	478,49304	9,99979	8,49325	11,50675
48	8,14495	9,99996	8,14495	11,85500	12	488,49708	9,99979	8,49729	11,50271
49	8,15391	9,99996	8,15391	11,84605	11	498,50108	9,99978	8,50130	11,49870
50	8,16268	9,99995	8,16268	11,83727	10	508,50504	9,99978	8,50527	11,49473
51	8,17128	9,99995	8,17128	11,82867	9	518,50897	9,99977	8,50920	11,49080
52	8,17971	9,99995	8,17971	11,82024	8	528,51287	9,99977	8,51310	11,48690
53	8,18798	9,99995	8,18798	11,81196	7	538,51673	9,99977	8,51696	11,48304
54	8,19610	9,99995	8,19610	11,80384	6	548,52055	9,99976	8,52079	11,47921
55	8,20407	9,99994	8,20407	11,79587	5	558,52434	9,99976	8,52459	11,47541
56	8,21189	9,99994	8,21189	11,78805	4	568,52810	9,99975	8,52835	11,47165
57	8,21953	9,99994	8,21953	11,78036	3	578,53183	9,99975	8,53208	11,46792
58	8,22713	9,99994	8,22713	11,77280	2	588,53552	9,99974	8,53578	11,46423
59	8,23456	9,99994	8,23456	11,76538	1	598,53919	9,99974	8,53945	11,46055
60	8,24186	9,99993	8,24186	11,75808	0	608,54282	9,99974	8,54308	11,45692
Co-sine Sine Co-tan. Tangent-M					Co-sine Sine Co-tan. Tangent-M				
89 Degrees.					88 Degrees.				

TABLE OF SINES AND TANGENTS. 145. 371

2 Degrees.					3 Degrees.				
M	Sine	Co-sine.	Tang.	Co-tang.	M	Sine	Co-sine.	Tang.	Co-tang.
0	8,54282	9,99974	8,54308	11,45692	60	8,71880	9,99940	8,71940	11,28060
1	8,54642	9,99973	8,54669	11,45331	59	8,72120	9,99940	8,72181	11,27819
2	8,54999	9,99973	8,55027	11,44973	58	8,72359	9,99939	8,72420	11,27580
3	8,55354	9,99972	8,55382	11,44618	57	8,72597	9,99938	8,72659	11,27341
4	8,55705	9,99972	8,55734	11,44266	56	8,72834	9,99938	8,72896	11,27104
5	8,56054	9,99971	8,56083	11,43917	55	8,73069	9,99937	8,73132	11,26868
6	8,56403	9,99971	8,56429	11,43571	54	8,73303	9,99936	8,73366	11,26634
7	8,56743	9,99970	8,56773	11,43227	53	8,73535	9,99936	8,73600	11,26400
8	8,57084	9,99970	8,57114	11,42886	52	8,73767	9,99935	8,73832	11,26168
9	8,57421	9,99969	8,57452	11,42548	51	8,73997	9,99934	8,74063	11,25937
10	8,57757	9,99969	8,57788	11,42212	50	8,74226	9,99934	8,74292	11,25708
11	8,58089	9,99968	8,58121	11,41879	49	8,74454	9,99933	8,74521	11,25479
12	8,58419	9,99968	8,58451	11,41548	48	8,74680	9,99932	8,74748	11,25252
13	8,58747	9,99967	8,58779	11,41221	47	8,74906	9,99932	8,74974	11,25026
14	8,59072	9,99967	8,59105	11,40895	46	8,75130	9,99931	8,75199	11,24801
15	8,59395	9,99966	8,59428	11,40572	45	8,75353	9,99930	8,75423	11,24577
16	8,59715	9,99966	8,59749	11,40251	44	8,75575	9,99929	8,75645	11,24355
17	8,60033	9,99965	8,60068	11,39932	43	8,75795	9,99929	8,75867	11,24133
18	8,60349	9,99965	8,60384	11,39616	42	8,76015	9,99928	8,76087	11,23913
19	8,60662	9,99964	8,60698	11,39302	41	8,76234	9,99927	8,76306	11,23694
20	8,60973	9,99964	8,61009	11,38991	40	8,76451	9,99926	8,76525	11,23475
21	8,61282	9,99963	8,61319	11,38681	39	8,76667	9,99926	8,76742	11,23258
22	8,61589	9,99963	8,61626	11,38374	38	8,76883	9,99925	8,76958	11,23042
23	8,61894	9,99962	8,61931	11,38069	37	8,77097	9,99924	8,77173	11,22827
24	8,62199	9,99962	8,62234	11,37766	36	8,77310	9,99923	8,77387	11,22613
25	8,62495	9,99961	8,62535	11,37465	35	8,77522	9,99923	8,77600	11,22400
26	8,62791	9,99961	8,62834	11,37166	34	8,77733	9,99922	8,77811	11,22189
27	8,63091	9,99960	8,63131	11,36869	33	8,77943	9,99921	8,78022	11,21978
28	8,63385	9,99960	8,63426	11,36574	32	8,78152	9,99920	8,78232	11,21768
29	8,63678	9,99959	8,63718	11,36282	31	8,78360	9,99920	8,78441	11,21559
30	8,63968	9,99959	8,64009	11,35991	30	8,78568	9,99919	8,78649	11,21351
31	8,64256	9,99958	8,64298	11,35702	29	8,78774	9,99918	8,78855	11,21145
32	8,64543	9,99958	8,64585	11,35415	28	8,78979	9,99917	8,79061	11,20939
33	8,64827	9,99957	8,64870	11,35130	27	8,79183	9,99917	8,79266	11,20734
34	8,65110	9,99956	8,65154	11,34846	26	8,79386	9,99916	8,79470	11,20530
35	8,65391	9,99956	8,65435	11,34565	25	8,79588	9,99915	8,79673	11,20327
36	8,65670	9,99955	8,65715	11,34285	24	8,79789	9,99914	8,79875	11,20125
37	8,65947	9,99955	8,65993	11,34007	23	8,79990	9,99913	8,80076	11,19924
38	8,66223	9,99954	8,66269	11,33731	22	8,80189	9,99913	8,80277	11,19723
39	8,66497	9,99954	8,66543	11,33457	21	8,80388	9,99912	8,80476	11,19524
40	8,66769	9,99953	8,66816	11,33184	20	8,80585	9,99911	8,80674	11,19326
41	8,67039	9,99952	8,67087	11,32913	19	8,80782	9,99910	8,80872	11,19128
42	8,67308	9,99952	8,67356	11,32644	18	8,80978	9,99909	8,81068	11,18932
43	8,67575	9,99951	8,67624	11,32376	17	8,81173	9,99909	8,81264	11,18736
44	8,67841	9,99951	8,67890	11,32110	16	8,81367	9,99908	8,81459	11,18541
45	8,68104	9,99950	8,68154	11,31846	15	8,81560	9,99907	8,81653	11,18347
46	8,68367	9,99949	8,68417	11,31583	14	8,81752	9,99906	8,81846	11,18154
47	8,68627	9,99949	8,68678	11,31322	13	8,81944	9,99905	8,82038	11,17962
48	8,68886	9,99948	8,68938	11,31062	12	8,82134	9,99904	8,82230	11,17770
49	8,69144	9,99947	8,69196	11,30804	11	8,82322	9,99904	8,82420	11,17580
50	8,69400	9,99947	8,69453	11,30547	10	8,82513	9,99903	8,82610	11,17390
51	8,69654	9,99946	8,69708	11,30292	9	8,82701	9,99902	8,82799	11,17201
52	8,69907	9,99946	8,69962	11,30038	8	8,82888	9,99901	8,82987	11,17013
53	8,70159	9,99945	8,70214	11,29786	7	8,83075	9,99900	8,83175	11,16825
54	8,70409	9,99944	8,70465	11,29535	6	8,83261	9,99899	8,83361	11,16639
55	8,70658	9,99944	8,70714	11,29286	5	8,83446	9,99898	8,83547	11,16453
56	8,70905	9,99943	8,70962	11,29038	4	8,83630	9,99898	8,83732	11,16268
57	8,71151	9,99942	8,71208	11,28792	3	8,83813	9,99897	8,83916	11,16084
58	8,71395	9,99942	8,71453	11,28547	2	8,83996	9,99896	8,84100	11,15900
59	8,71638	9,99941	8,71697	11,28303	1	8,84177	9,99895	8,84282	11,15718
60	8,71880	9,99940	8,71940	11,28060	0	8,84358	9,99894	8,84464	11,15536
Co-sine Sine Co-tan Tangent. M					Co-sine Sine Co-tan Tangent. M				

87 Degrees.

86 Degrees.

372 TABLE OF SINES AND TANGENTS. 145.

4 Degrees.					5 Degrees.				
M	Sine	Co sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	8,84350	9,99894	8,84464	11,15536	60	8,94030	9,99834	8,94195	11,05805
1	8,84539	9,99893	8,84646	11,15354	59	8,94174	9,99833	8,94340	11,05660
2	8,84718	9,99892	8,84826	11,15174	58	8,94317	9,99832	8,94485	11,05515
3	8,84897	9,99891	8,85006	11,14994	57	8,94461	9,99831	8,94630	11,05370
4	8,85075	9,99891	8,85185	11,14815	56	8,94603	9,99830	8,94773	11,05227
5	8,85252	9,99890	8,85363	11,14637	55	8,94746	9,99829	8,94917	11,05083
6	8,85429	9,99889	8,85540	11,14460	54	8,94887	9,99828	8,95060	11,04940
7	8,85606	9,99888	8,85717	11,14283	53	8,95029	9,99827	8,95202	11,04798
8	8,85780	9,99887	8,85893	11,14107	52	8,95170	9,99825	8,95344	11,04656
9	8,85955	9,99886	8,86069	11,13931	51	8,95310	9,99824	8,95486	11,04514
10	8,86128	9,99885	8,86243	11,13757	50	8,95450	9,99823	8,95627	11,04373
11	8,86301	9,99884	8,86417	11,13583	49	8,95589	9,99822	8,95767	11,04233
12	8,86474	9,99883	8,86591	11,13409	48	8,95728	9,99821	8,95908	11,04092
13	8,86645	9,99882	8,86763	11,13237	47	8,95867	9,99820	8,96047	11,03953
14	8,86816	9,99881	8,86935	11,13065	46	8,96005	9,99819	8,96187	11,03813
15	8,86987	9,99880	8,87106	11,12894	45	8,96143	9,99817	8,96325	11,03675
16	8,87156	9,99879	8,87277	11,12723	44	8,96280	9,99816	8,96464	11,03536
17	8,87325	9,99879	8,87447	11,12553	43	8,96417	9,99815	8,96602	11,03398
18	8,87494	9,99878	8,87616	11,12384	42	8,96553	9,99814	8,96739	11,03261
19	8,87661	9,99877	8,87785	11,12215	41	8,96689	9,99813	8,96877	11,03123
20	8,87829	9,99876	8,87953	11,12047	40	8,96825	9,99812	8,97013	11,02987
21	8,87995	9,99875	8,88120	11,11880	39	8,96960	9,99810	8,97150	11,02850
22	8,88161	9,99874	8,88287	11,11713	38	8,97095	9,99809	8,97285	11,02715
23	8,88326	9,99873	8,88453	11,11547	37	8,97229	9,99808	8,97421	11,02579
24	8,88490	9,99872	8,88618	11,11382	36	8,97363	9,99807	8,97556	11,02444
25	8,88654	9,99871	8,88783	11,11217	35	8,97496	9,99806	8,97691	11,02309
26	8,88817	9,99870	8,88948	11,11052	34	8,97629	9,99804	8,97825	11,02175
27	8,88980	9,99869	8,89111	11,10889	33	8,97762	9,99803	8,97959	11,02041
28	8,89142	9,99868	8,89274	11,10726	32	8,97894	9,99802	8,98092	11,01908
29	8,89304	9,99867	8,89437	11,10563	31	8,98026	9,99801	8,98225	11,01775
30	8,89464	9,99866	8,89598	11,10402	30	8,98157	9,99800	8,98358	11,01642
31	8,89625	9,99865	8,89760	11,10240	29	8,98288	9,99798	8,98490	11,01510
32	8,89784	9,99864	8,89920	11,10080	28	8,98419	9,99797	8,98622	11,01378
33	8,89943	9,99863	8,90080	11,09920	27	8,98549	9,99796	8,98753	11,01247
34	8,90102	9,99862	8,90240	11,09760	26	8,98679	9,99795	8,98884	11,01116
35	8,90260	9,99861	8,90399	11,09601	25	8,98808	9,99793	8,99015	11,00985
36	8,90417	9,99860	8,90557	11,09443	24	8,98937	9,99792	8,99145	11,00855
37	8,90574	9,99859	8,90715	11,09285	23	8,99066	9,99791	8,99275	11,00725
38	8,90730	9,99858	8,90872	11,09128	22	8,99194	9,99790	8,99405	11,00595
39	8,90885	9,99857	8,91029	11,08971	21	8,99322	9,99788	8,99534	11,00466
40	8,91040	9,99856	8,91185	11,08815	20	8,99450	9,99787	8,99662	11,00338
41	8,91195	9,99855	8,91340	11,08660	19	8,99577	9,99786	8,99791	11,00209
42	8,91349	9,99854	8,91495	11,08505	18	8,99704	9,99785	8,99919	11,00081
43	8,91502	9,99853	8,91650	11,08350	17	8,99830	9,99783	9,00046	10,99954
44	8,91655	9,99852	8,91803	11,08197	16	8,99956	9,99782	9,00174	10,99826
45	8,91807	9,99851	8,91957	11,08043	15	9,00082	9,99781	9,00301	10,99699
46	8,91959	9,99850	8,92110	11,07890	14	9,00207	9,99780	9,00427	10,99573
47	8,92110	9,99848	8,92262	11,07738	13	9,00332	9,99778	9,00553	10,99447
48	8,92261	9,99847	8,92414	11,07586	12	9,00456	9,99777	9,00679	10,99321
49	8,92411	9,99846	8,92565	11,07435	11	9,00581	9,99776	9,00805	10,99195
50	8,92561	9,99845	8,92716	11,07284	10	9,00704	9,99775	9,00930	10,99070
51	8,92710	9,99844	8,92866	11,07134	9	9,00828	9,99773	9,01055	10,98945
52	8,92859	9,99843	8,93016	11,06984	8	9,00951	9,99772	9,01179	10,98821
53	8,93007	9,99842	8,93165	11,06835	7	9,01074	9,99771	9,01303	10,98697
54	8,93154	9,99841	8,93313	11,06687	6	9,01196	9,99769	9,01427	10,98573
55	8,93301	9,99840	8,93462	11,06538	5	9,01318	9,99768	9,01550	10,98450
56	8,93448	9,99839	8,93609	11,06391	4	9,01440	9,99767	9,01673	10,98327
57	8,93594	9,99838	8,93756	11,06244	3	9,01561	9,99765	9,01796	10,98204
58	8,93740	9,99837	8,93903	11,06097	2	9,01682	9,99764	9,01918	10,98082
59	8,93885	9,99836	8,94049	11,05951	1	9,01803	9,99763	9,02040	10,97960
60	8,94030	9,99834	8,94195	11,05805	0	9,01923	9,99761	9,02162	10,97838
Co-sine	Sine	Co-tan.	Tangent.	M	Co-sine	Sine	Co-tan.	Tangent.	M
85 Degrees.					84 Degrees.				

TABLE OF SINES AND TANGENTS. 145. 373

6 Degrees.					7 Degrees.				
M	Sine	Co. fine.	Tang.	Co-tang.	M	Sine	Co-fine	Tang.	Co-tang.
0	9,01523	9,9976	9,02162	10,97838	60	9,08589	9,99675	9,08914	10,91086
1	9,02043	9,99760	9,02283	10,97717	59	9,08692	9,99674	9,09019	10,90981
2	9,02163	9,99759	9,02404	10,97596	58	9,08795	9,99672	9,09123	10,90877
3	9,02283	9,99757	9,02525	10,97475	57	9,08897	9,99670	9,09227	10,90773
4	9,02402	9,99756	9,02645	10,97355	56	9,08999	9,99669	9,09330	10,90670
5	9,02520	9,99755	9,02766	10,97234	55	9,09101	9,99667	9,09434	10,90566
6	9,02639	9,99753	9,02885	10,97115	54	9,09202	9,99666	9,09537	10,90463
7	9,02757	9,99752	9,03005	10,96995	53	9,09304	9,99664	9,09640	10,90360
8	9,02874	9,99751	9,03124	10,96876	52	9,09405	9,99663	9,09742	10,90258
9	9,02992	9,99749	9,03242	10,96758	51	9,09506	9,99661	9,09845	10,90155
10	9,03109	9,99748	9,03361	10,96639	50	9,09606	9,99659	9,09947	10,90053
11	9,03226	9,99747	9,03479	10,96521	49	9,09707	9,99658	9,10049	10,89951
12	9,03342	9,99745	9,03597	10,96403	48	9,09807	9,99656	9,10150	10,89850
13	9,03458	9,99744	9,03714	10,96286	47	9,09907	9,99655	9,10252	10,89748
14	9,03574	9,99742	9,03832	10,96168	46	9,10006	9,99653	9,10353	10,89647
15	9,03690	9,99741	9,03948	10,96052	45	9,10106	9,99651	9,10454	10,89546
16	9,03805	9,99740	9,04065	10,95935	44	9,10205	9,99650	9,10555	10,89445
17	9,03920	9,99738	9,04181	10,95819	43	9,10304	9,99648	9,10656	10,89344
18	9,04034	9,99737	9,04297	10,95703	42	9,10402	9,99647	9,10756	10,89244
19	9,04149	9,99736	9,04413	10,95587	41	9,10501	9,99645	9,10856	10,89144
20	9,04262	9,99734	9,04528	10,95472	40	9,10599	9,99643	9,10956	10,89044
21	9,04376	9,99733	9,04643	10,95357	39	9,10697	9,99642	9,11056	10,88944
22	9,04490	9,99731	9,04758	10,95242	38	9,10795	9,99640	9,11155	10,88845
23	9,04603	9,99730	9,04873	10,95127	37	9,10893	9,99638	9,11254	10,88746
24	9,04715	9,99728	9,04987	10,95013	36	9,10990	9,99637	9,11353	10,88647
25	9,04828	9,99727	9,05101	10,94899	35	9,11087	9,99635	9,11452	10,88548
26	9,04940	9,99726	9,05214	10,94786	34	9,11184	9,99633	9,11551	10,88449
27	9,05052	9,99724	9,05328	10,94672	33	9,11281	9,99632	9,11649	10,88351
28	9,05164	9,99723	9,05441	10,94559	32	9,11377	9,99630	9,11747	10,88253
29	9,05275	9,99721	9,05553	10,94447	31	9,11474	9,99629	9,11845	10,88155
30	9,05386	9,99720	9,05666	10,94334	30	9,11570	9,99627	9,11943	10,88057
31	9,05497	9,99718	9,05778	10,94222	29	9,11666	9,99625	9,12040	10,87960
32	9,05607	9,99717	9,05890	10,94110	28	9,11761	9,99624	9,12138	10,87862
33	9,05717	9,99716	9,06002	10,93998	27	9,11857	9,99622	9,12235	10,87765
34	9,05827	9,99714	9,06113	10,93887	26	9,11952	9,99620	9,12332	10,87668
35	9,05937	9,99713	9,06224	10,93776	25	9,12047	9,99618	9,12428	10,87572
36	9,06046	9,99711	9,06335	10,93665	24	9,12142	9,99617	9,12525	10,87475
37	9,06155	9,99710	9,06445	10,93555	23	9,12236	9,99615	9,12621	10,87379
38	9,06264	9,99708	9,06556	10,93444	22	9,12331	9,99613	9,12717	10,87283
39	9,06372	9,99707	9,06666	10,93334	21	9,12425	9,99612	9,12813	10,87187
40	9,06481	9,99705	9,06775	10,93225	20	9,12519	9,99610	9,12909	10,87091
41	9,06589	9,99704	9,06885	10,93115	19	9,12612	9,99608	9,13004	10,86996
42	9,06696	9,99702	9,06994	10,93006	18	9,12706	9,99607	9,13099	10,86901
43	9,06804	9,99701	9,07103	10,92897	17	9,12799	9,99605	9,13194	10,86806
44	9,06911	9,99699	9,07211	10,92789	16	9,12892	9,99603	9,13289	10,86711
45	9,07018	9,99698	9,07320	10,92680	15	9,12985	9,99601	9,13384	10,86616
46	9,07124	9,99696	9,07428	10,92572	14	9,13078	9,99600	9,13478	10,86522
47	9,07231	9,99695	9,07536	10,92464	13	9,13171	9,99598	9,13573	10,86427
48	9,07337	9,99693	9,07643	10,92357	12	9,13263	9,99596	9,13667	10,86333
49	9,07442	9,99692	9,07751	10,92249	11	9,13355	9,99595	9,13761	10,86239
50	9,07548	9,99690	9,07858	10,92142	10	9,13447	9,99593	9,13854	10,86146
51	9,07653	9,99689	9,07964	10,92036	9	9,13539	9,99591	9,13948	10,86052
52	9,07758	9,99687	9,08071	10,91929	8	9,13630	9,99589	9,14041	10,85959
53	9,07863	9,99686	9,08177	10,91823	7	9,13722	9,99588	9,14134	10,85866
54	9,07968	9,99684	9,08283	10,91717	6	9,13813	9,99586	9,14227	10,85773
55	9,08072	9,99683	9,08389	10,91611	5	9,13904	9,99584	9,14320	10,85680
56	9,08176	9,99681	9,08495	10,91505	4	9,13994	9,99582	9,14412	10,85588
57	9,08280	9,99680	9,08600	10,91400	3	9,14085	9,99581	9,14504	10,85496
58	9,08383	9,99678	9,08705	10,91295	2	9,14175	9,99579	9,14597	10,85403
59	9,08486	9,99677	9,08810	10,91190	1	9,14266	9,99577	9,14688	10,85312
60	9,08589	9,99675	9,08914	10,91086	0	9,14356	9,99575	9,14780	10,85220
Co-fine.	Sine	Co-tan.	Tangent.	M	Co-fine.	Sine	Co-tan.	Tangent.	M
83 Degrees.					82 Degrees.				

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8 Degrees.					9 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9,14356	9,99575	9,14780	10,85220	60	9,19433	9,99462	9,19971	10,80029
1	9,14445	9,99573	9,14872	10,85128	59	9,19513	9,99460	9,20053	10,79947
2	9,14535	9,99572	9,14963	10,85037	58	9,19592	9,99458	9,20134	10,79866
3	9,14624	9,99570	9,15054	10,84946	57	9,19672	9,99456	9,20216	10,79784
4	9,14714	9,99568	9,15145	10,84855	56	9,19751	9,99454	9,20297	10,79703
5	9,14803	9,99566	9,15236	10,84764	55	9,19830	9,99452	9,20378	10,79622
6	9,14891	9,99565	9,15327	10,84673	54	9,19909	9,99450	9,20459	10,79541
7	9,14980	9,99563	9,15417	10,84583	53	9,19988	9,99448	9,20540	10,79460
8	9,15069	9,99561	9,15508	10,84492	52	9,20067	9,99446	9,20621	10,79379
9	9,15157	9,99559	9,15598	10,84402	51	9,20145	9,99444	9,20701	10,79299
10	9,15245	9,99557	9,15688	10,84312	50	9,20223	9,99442	9,20782	10,79218
11	9,15333	9,99556	9,15777	10,84223	49	9,20302	9,99440	9,20862	10,79138
12	9,15421	9,99554	9,15867	10,84133	48	9,20380	9,99438	9,20942	10,79058
13	9,15508	9,99552	9,15956	10,84044	47	9,20458	9,99436	9,21022	10,78978
14	9,15596	9,99550	9,16046	10,83954	46	9,20535	9,99434	9,21102	10,78898
15	9,15683	9,99548	9,16135	10,83865	45	9,20613	9,99432	9,21182	10,78818
16	9,15770	9,99546	9,16224	10,83776	44	9,20691	9,99429	9,21261	10,78739
17	9,15857	9,99545	9,16312	10,83688	43	9,20768	9,99427	9,21341	10,78659
18	9,15944	9,99543	9,16401	10,83599	42	9,20845	9,99425	9,21420	10,78580
19	9,16030	9,99541	9,16489	10,83511	41	9,20922	9,99423	9,21499	10,78501
20	9,16116	9,99539	9,16577	10,83423	40	9,20999	9,99421	9,21578	10,78422
21	9,16203	9,99537	9,16665	10,83335	39	9,21076	9,99419	9,21657	10,78343
22	9,16289	9,99535	9,16753	10,83247	38	9,21153	9,99417	9,21736	10,78264
23	9,16374	9,99533	9,16841	10,83159	37	9,21229	9,99415	9,21814	10,78186
24	9,16460	9,99532	9,16928	10,83072	36	9,21306	9,99413	9,21893	10,78107
25	9,16545	9,99530	9,17016	10,82984	35	9,21382	9,99411	9,21971	10,78029
26	9,16631	9,99528	9,17103	10,82897	34	9,21458	9,99409	9,22049	10,77951
27	9,16716	9,99526	9,17190	10,82810	33	9,21534	9,99407	9,22127	10,77873
28	9,16801	9,99524	9,17277	10,82723	32	9,21610	9,99404	9,22205	10,77795
29	9,16886	9,99522	9,17363	10,82637	31	9,21685	9,99402	9,22283	10,77717
30	9,16970	9,99520	9,17450	10,82550	30	9,21761	9,99400	9,22361	10,77639
31	9,17055	9,99518	9,17536	10,82464	29	9,21836	9,99398	9,22438	10,77562
32	9,17139	9,99517	9,17622	10,82378	28	9,21912	9,99396	9,22516	10,77484
33	9,17223	9,99515	9,17708	10,82292	27	9,21987	9,99394	9,22593	10,77407
34	9,17307	9,99513	9,17794	10,82206	26	9,22062	9,99392	9,22670	10,77330
35	9,17391	9,99511	9,17880	10,82120	25	9,22137	9,99390	9,22747	10,77253
36	9,17474	9,99509	9,17965	10,82035	24	9,22211	9,99388	9,22824	10,77176
37	9,17558	9,99507	9,18051	10,81949	23	9,22286	9,99385	9,22901	10,77099
38	9,17641	9,99505	9,18136	10,81864	22	9,22361	9,99383	9,22977	10,77023
39	9,17724	9,99503	9,18221	10,81779	21	9,22435	9,99381	9,23054	10,76946
40	9,17807	9,99501	9,18306	10,81694	20	9,22509	9,99379	9,23130	10,76870
41	9,17890	9,99499	9,18391	10,81609	19	9,22583	9,99377	9,23206	10,76793
42	9,17973	9,99497	9,18475	10,81525	18	9,22657	9,99375	9,23283	10,76717
43	9,18055	9,99495	9,18560	10,81440	17	9,22731	9,99373	9,23359	10,76641
44	9,18137	9,99494	9,18644	10,81356	16	9,22805	9,99370	9,23435	10,76565
45	9,18220	9,99492	9,18728	10,81272	15	9,22878	9,99368	9,23510	10,76490
46	9,18302	9,99490	9,18812	10,81188	14	9,22952	9,99366	9,23586	10,76414
47	9,18385	9,99488	9,18896	10,81104	13	9,23025	9,99364	9,23661	10,76339
48	9,18465	9,99486	9,18979	10,81021	12	9,23098	9,99362	9,23737	10,76263
49	9,18547	9,99484	9,19063	10,80937	11	9,23171	9,99359	9,23812	10,76188
50	9,18628	9,99482	9,19146	10,80854	10	9,23244	9,99357	9,23887	10,76113
51	9,18709	9,99480	9,19229	10,80771	9	9,23317	9,99355	9,23962	10,76038
52	9,18790	9,99478	9,19312	10,80688	8	9,23390	9,99353	9,24037	10,75963
53	9,18871	9,99476	9,19395	10,80605	7	9,23462	9,99351	9,24112	10,75888
54	9,18952	9,99474	9,19478	10,80522	6	9,23535	9,99348	9,24186	10,75813
55	9,19033	9,99472	9,19561	10,80439	5	9,23607	9,99346	9,24261	10,75739
56	9,19113	9,99470	9,19643	10,80357	4	9,23679	9,99344	9,24335	10,75665
57	9,19193	9,99468	9,19725	10,80275	3	9,23752	9,99342	9,24410	10,75590
58	9,19273	9,99466	9,19807	10,80193	2	9,23823	9,99340	9,24484	10,75516
59	9,19353	9,99464	9,19889	10,80111	1	9,23895	9,99337	9,24558	10,75442
60	9,19433	9,99462	9,19971	10,80029	0	9,23967	9,99335	9,24632	10,75368
81 Degrees.					82 Degrees.				
Co-sine	Sine	Co-tan.	Tangent	M	Co-sine	Sine	Co-tan.	Tangent	M

TABLE OF SINES AND TANGENTS. 145. 375

10 Degrees.					11 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9,23967	9,99335	9,24632	10,75368	60	9,28060	9,99195	9,28865	10,71135
1	9,24039	9,99333	9,24706	10,75294	59	9,28125	9,99192	9,28933	10,71067
2	9,24110	9,99331	9,24779	10,75221	58	9,28190	9,99190	9,29000	10,71000
3	9,24181	9,99328	9,24853	10,75147	57	9,28254	9,99187	9,29067	10,70933
4	9,24253	9,99326	9,24926	10,75074	56	9,28319	9,99185	9,29134	10,70866
5	9,24324	9,99324	9,25000	10,75000	55	9,28384	9,99182	9,29201	10,70799
6	9,24395	9,99322	9,25073	10,74927	54	9,28448	9,99180	9,29268	10,70732
7	9,24466	9,99319	9,25146	10,74854	53	9,28512	9,99177	9,29335	10,70665
8	9,24536	9,99317	9,25219	10,74781	52	9,28577	9,99175	9,29402	10,70598
9	9,24607	9,99315	9,25292	10,74708	51	9,28641	9,99172	9,29468	10,70532
10	9,24677	9,99313	9,25365	10,74635	50	9,28705	9,99170	9,29535	10,70465
11	9,24748	9,99310	9,25437	10,74563	49	9,28769	9,99167	9,29601	10,70399
12	9,24818	9,99308	9,25510	10,74490	48	9,28833	9,99165	9,29668	10,70332
13	9,24888	9,99306	9,25582	10,74418	47	9,28896	9,99162	9,29734	10,70266
14	9,24958	9,99304	9,25655	10,74345	46	9,28960	9,99160	9,29800	10,70200
15	9,25028	9,99301	9,25727	10,74273	45	9,29024	9,99157	9,29866	10,70134
16	9,25098	9,99299	9,25799	10,74201	44	9,29087	9,99155	9,29932	10,70068
17	9,25168	9,99297	9,25871	10,74129	43	9,29150	9,99152	9,29998	10,70002
18	9,25237	9,99294	9,25943	10,74057	42	9,29214	9,99150	9,30064	10,69936
19	9,25307	9,99292	9,26015	10,73985	41	9,29277	9,99147	9,30130	10,69870
20	9,25376	9,99290	9,26086	10,73914	40	9,29340	9,99145	9,30195	10,69805
21	9,25445	9,99288	9,26158	10,73842	39	9,29403	9,99142	9,30261	10,69739
22	9,25514	9,99285	9,26229	10,73771	38	9,29466	9,99140	9,30326	10,69674
23	9,25583	9,99283	9,26301	10,73699	37	9,29529	9,99137	9,30391	10,69609
24	9,25652	9,99281	9,26372	10,73628	36	9,29591	9,99135	9,30457	10,69543
25	9,25721	9,99278	9,26443	10,73557	35	9,29654	9,99132	9,30522	10,69478
26	9,25790	9,99276	9,26514	10,73486	34	9,29716	9,99130	9,30587	10,69413
27	9,25858	9,99274	9,26585	10,73415	33	9,29779	9,99127	9,30652	10,69348
28	9,25927	9,99272	9,26655	10,73343	32	9,29841	9,99124	9,30717	10,69283
29	9,25995	9,99269	9,26726	10,73274	31	9,29903	9,99122	9,30782	10,69218
30	9,26063	9,99267	9,26797	10,73203	30	9,29966	9,99119	9,30846	10,69154
31	9,26131	9,99264	9,26867	10,73133	29	9,30028	9,99117	9,30911	10,69089
32	9,26199	9,99262	9,26937	10,73062	28	9,30090	9,99114	9,30975	10,69025
33	9,26267	9,99260	9,27008	10,72992	27	9,30151	9,99112	9,31040	10,68960
34	9,26335	9,99257	9,27078	10,72922	26	9,30213	9,99109	9,31104	10,68896
35	9,26403	9,99255	9,27148	10,72852	25	9,30275	9,99106	9,31168	10,68832
36	9,26470	9,99252	9,27218	10,72782	24	9,30336	9,99104	9,31233	10,68767
37	9,26538	9,99250	9,27288	10,72712	23	9,30398	9,99101	9,31297	10,68703
38	9,26605	9,99248	9,27357	10,72643	22	9,30459	9,99099	9,31361	10,68639
39	9,26672	9,99245	9,27427	10,72573	21	9,30521	9,99096	9,31425	10,68575
40	9,26739	9,99243	9,27496	10,72504	20	9,30582	9,99093	9,31489	10,68511
41	9,26806	9,99241	9,27566	10,72434	19	9,30643	9,99091	9,31552	10,68448
42	9,26873	9,99238	9,27635	10,72365	18	9,30704	9,99088	9,31616	10,68384
43	9,26940	9,99236	9,27704	10,72296	17	9,30765	9,99086	9,31679	10,68321
44	9,27007	9,99233	9,27773	10,72227	16	9,30826	9,99083	9,31743	10,68257
45	9,27073	9,99231	9,27842	10,72158	15	9,30887	9,99080	9,31806	10,68194
46	9,27140	9,99229	9,27911	10,72089	14	9,30947	9,99078	9,31870	10,68130
47	9,27206	9,99226	9,27980	10,72020	13	9,31008	9,99075	9,31933	10,68067
48	9,27273	9,99224	9,28049	10,71951	12	9,31068	9,99072	9,31996	10,68004
49	9,27339	9,99221	9,28117	10,71883	11	9,31129	9,99070	9,32059	10,67941
50	9,27405	9,99219	9,28186	10,71814	10	9,31189	9,99067	9,32122	10,67878
51	9,27471	9,99217	9,28254	10,71746	9	9,31250	9,99064	9,32185	10,67815
52	9,27537	9,99214	9,28323	10,71677	8	9,31310	9,99062	9,32248	10,67752
53	9,27602	9,99212	9,28391	10,71609	7	9,31370	9,99059	9,32311	10,67689
54	9,27668	9,99209	9,28459	10,71541	6	9,31430	9,99056	9,32373	10,67627
55	9,27734	9,99207	9,28527	10,71473	5	9,31490	9,99054	9,32436	10,67564
56	9,27799	9,99204	9,28595	10,71405	4	9,31549	9,99051	9,32498	10,67502
57	9,27864	9,99202	9,28662	10,71338	3	9,31609	9,99048	9,32561	10,67439
58	9,27930	9,99200	9,28730	10,71270	2	9,31669	9,99046	9,32623	10,67377
59	9,27995	9,99197	9,28798	10,71202	1	9,31728	9,99043	9,32685	10,67315
60	9,28060	9,99195	9,28865	10,71135	0	9,31788	9,99040	9,32747	10,67253
79 Degrees.					78 Degrees.				
Co-sine	Sine	Co-tan.	Tangent	M	Co-sine	Sine	Co-tan.	Tangent	M

376 TABLE OF SINES AND TANGENTS. 145.

12 Degrees.					13 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9,31788	9,99040	9,32747	10,67253	60	9,35209	9,98872	9,36336	10,63664
1	9,31847	9,99038	9,32810	10,67190	59	9,35263	9,98869	9,36394	10,63606
2	9,31907	9,99035	9,32872	10,67128	58	9,35318	9,98867	9,36452	10,63548
3	9,31966	9,99032	9,32933	10,67067	57	9,35373	9,98864	9,36509	10,63491
4	9,32025	9,99030	9,32995	10,67005	56	9,35427	9,98861	9,36566	10,63434
5	9,32084	9,99027	9,33057	10,66943	55	9,35481	9,98858	9,36624	10,63376
6	9,32143	9,99024	9,33119	10,66881	54	9,35536	9,98855	9,36681	10,63319
7	9,32202	9,99022	9,33180	10,66820	53	9,35590	9,98852	9,36738	10,63262
8	9,32261	9,99019	9,33242	10,66758	52	9,35644	9,98849	9,36795	10,63205
9	9,32319	9,99016	9,33303	10,66697	51	9,35698	9,98846	9,36852	10,63148
10	9,32378	9,99013	9,33365	10,66635	50	9,35752	9,98843	9,36909	10,63091
11	9,32437	9,99011	9,33426	10,66574	49	9,35806	9,98840	9,36966	10,63034
12	9,32495	9,99008	9,33487	10,66513	48	9,35860	9,98837	9,37023	10,62977
13	9,32553	9,99005	9,33548	10,66452	47	9,35914	9,98834	9,37080	10,62920
14	9,32612	9,99002	9,33609	10,66391	46	9,35968	9,98831	9,37137	10,62863
15	9,32670	9,99000	9,33670	10,66330	45	9,36022	9,98828	9,37193	10,62806
16	9,32728	9,98997	9,33731	10,66269	44	9,36075	9,98825	9,37250	10,62750
17	9,32786	9,98994	9,33792	10,66208	43	9,36129	9,98822	9,37306	10,62694
18	9,32844	9,98991	9,33853	10,66147	42	9,36182	9,98819	9,37363	10,62637
19	9,32902	9,98989	9,33913	10,66087	41	9,36236	9,98816	9,37419	10,62581
20	9,32960	9,98986	9,33974	10,66026	40	9,36289	9,98813	9,37476	10,62524
21	9,33018	9,98983	9,34034	10,65966	39	9,36342	9,98810	9,37532	10,62468
22	9,33075	9,98980	9,34095	10,65905	38	9,36395	9,98807	9,37588	10,62412
23	9,33133	9,98978	9,34155	10,65845	37	9,36449	9,98804	9,37644	10,62356
24	9,33190	9,98975	9,34215	10,65785	36	9,36502	9,98801	9,37700	10,62300
25	9,33248	9,98972	9,34276	10,65724	35	9,36555	9,98798	9,37756	10,62244
26	9,33305	9,98969	9,34336	10,65664	34	9,36607	9,98795	9,37812	10,62188
27	9,33362	9,98967	9,34396	10,65604	33	9,36660	9,98792	9,37868	10,62132
28	9,33420	9,98964	9,34456	10,65544	32	9,36713	9,98789	9,37924	10,62076
29	9,33477	9,98961	9,34516	10,65484	31	9,36766	9,98786	9,37980	10,62020
30	9,33534	9,98958	9,34576	10,65424	30	9,36819	9,98783	9,38035	10,61965
31	9,33591	9,98955	9,34635	10,65365	29	9,36871	9,98780	9,38091	10,61909
32	9,33647	9,98953	9,34695	10,65305	28	9,36924	9,98777	9,38147	10,61853
33	9,33704	9,98950	9,34755	10,65245	27	9,36976	9,98774	9,38202	10,61798
34	9,33761	9,98947	9,34814	10,65186	26	9,37028	9,98771	9,38257	10,61743
35	9,33818	9,98944	9,34874	10,65126	25	9,37081	9,98768	9,38313	10,61687
36	9,33874	9,98941	9,34933	10,65067	24	9,37133	9,98765	9,38368	10,61632
37	9,33931	9,98938	9,34992	10,65008	23	9,37185	9,98762	9,38423	10,61577
38	9,33987	9,98936	9,35051	10,64949	22	9,37237	9,98759	9,38479	10,61521
39	9,34043	9,98933	9,35111	10,64889	21	9,37289	9,98756	9,38534	10,61466
40	9,34100	9,98930	9,35170	10,64830	20	9,37341	9,98753	9,38589	10,61411
41	9,34156	9,98927	9,35229	10,64771	19	9,37393	9,98750	9,38644	10,61356
42	9,34212	9,98924	9,35288	10,64712	18	9,37445	9,98746	9,38699	10,61301
43	9,34268	9,98921	9,35346	10,64653	17	9,37497	9,98743	9,38754	10,61246
44	9,34324	9,98919	9,35405	10,64595	16	9,37549	9,98740	9,38808	10,61192
45	9,34380	9,98916	9,35464	10,64536	15	9,37600	9,98737	9,38863	10,61137
46	9,34436	9,98913	9,35523	10,64477	14	9,37652	9,98734	9,38918	10,61082
47	9,34491	9,98910	9,35581	10,64419	13	9,37703	9,98731	9,38972	10,61028
48	9,34547	9,98907	9,35640	10,64360	12	9,37755	9,98728	9,39027	10,60973
49	9,34602	9,98904	9,35698	10,64302	11	9,37806	9,98725	9,39082	10,60918
50	9,34658	9,98901	9,35757	10,64243	10	9,37858	9,98722	9,39136	10,60864
51	9,34713	9,98898	9,35815	10,64185	9	9,37909	9,98719	9,39190	10,60810
52	9,34769	9,98896	9,35873	10,64127	8	9,37960	9,98715	9,39245	10,60755
53	9,34824	9,98893	9,35931	10,64069	7	9,38011	9,98712	9,39299	10,60701
54	9,34879	9,98890	9,35989	10,64011	6	9,38062	9,98709	9,39353	10,60647
55	9,34934	9,98887	9,36047	10,63953	5	9,38113	9,98706	9,39407	10,60593
56	9,34989	9,98884	9,36105	10,63895	4	9,38164	9,98703	9,39461	10,60539
57	9,35044	9,98881	9,36163	10,63837	3	9,38215	9,98700	9,39515	10,60485
58	9,35099	9,98878	9,36221	10,63779	2	9,38266	9,98697	9,39569	10,60431
59	9,35154	9,98875	9,36279	10,63721	1	9,38317	9,98694	9,39623	10,60377
60	9,35209	9,98872	9,36336	10,63664	0	9,38368	9,98690	9,39677	10,60323
Co-sine	Sine	Co-tan.	Tangent	M	Co-sine	Sine	Co-tan.	Tangent	M
77 Degrees.					76 Degrees.				

TABLE OF SINES AND TANGENTS. 145. 377

14 Degrees.					15 Degrees.				
M	Sine.	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9.38368	9.98690	9.39677	10.60323	60	9.41300	9.98494	9.42805	10.57195
1	9.38418	9.98687	9.39731	10.60269	59	9.41347	9.98491	9.42856	10.57144
2	9.38469	9.98684	9.39785	10.60215	58	9.41394	9.98488	9.42906	10.57094
3	9.38519	9.98681	9.39838	10.60162	57	9.41441	9.98484	9.42957	10.57043
4	9.38570	9.98678	9.39892	10.60108	56	9.41488	9.98481	9.43007	10.56993
5	9.38620	9.98675	9.39945	10.60055	55	9.41535	9.98477	9.43057	10.56943
6	9.38670	9.98671	9.39999	10.60001	54	9.41582	9.98474	9.43108	10.56892
7	9.38721	9.98668	9.40052	10.59948	53	9.41628	9.98471	9.43158	10.56842
8	9.38771	9.98665	9.40106	10.59894	52	9.41675	9.98467	9.43208	10.56792
9	9.38821	9.98662	9.40159	10.59841	51	9.41722	9.98464	9.43258	10.56742
10	9.38871	9.98659	9.40212	10.59788	50	9.41768	9.98460	9.43308	10.56692
11	9.38921	9.98656	9.40266	10.59734	49	9.41815	9.98457	9.43358	10.56642
12	9.38971	9.98652	9.40319	10.59681	48	9.41861	9.98453	9.43408	10.56592
13	9.39021	9.98649	9.40372	10.59628	47	9.41908	9.98450	9.43458	10.56542
14	9.39071	9.98646	9.40425	10.59575	46	9.41954	9.98447	9.43508	10.56492
15	9.39121	9.98643	9.40478	10.59522	45	9.42001	9.98443	9.43558	10.56442
16	9.39170	9.98640	9.40531	10.59469	44	9.42047	9.98440	9.43607	10.56393
17	9.39220	9.98636	9.40584	10.59416	43	9.42093	9.98436	9.43657	10.56343
18	9.39270	9.98633	9.40636	10.59364	42	9.42139	9.98433	9.43707	10.56293
19	9.39319	9.98630	9.40689	10.59311	41	9.42186	9.98429	9.43756	10.56244
20	9.39369	9.98627	9.40742	10.59258	40	9.42232	9.98426	9.43806	10.56194
21	9.39418	9.98623	9.40795	10.59205	39	9.42278	9.98422	9.43855	10.56145
22	9.39467	9.98620	9.40847	10.59153	38	9.42324	9.98419	9.43905	10.56095
23	9.39517	9.98617	9.40900	10.59100	37	9.42370	9.98415	9.43954	10.56046
24	9.39566	9.98614	9.40952	10.59048	36	9.42416	9.98412	9.44004	10.55996
25	9.39615	9.98610	9.41005	10.58995	35	9.42461	9.98409	9.44053	10.55947
26	9.39664	9.98607	9.41057	10.58943	34	9.42507	9.98405	9.44102	10.55898
27	9.39713	9.98604	9.41109	10.58891	33	9.42553	9.98402	9.44151	10.55849
28	9.39762	9.98601	9.41161	10.58839	32	9.42599	9.98398	9.44201	10.55799
29	9.39811	9.98597	9.41214	10.58786	31	9.42644	9.98395	9.44250	10.55750
30	9.39860	9.98594	9.41266	10.58734	30	9.42690	9.98391	9.44299	10.55701
31	9.39909	9.98591	9.41318	10.58682	29	9.42735	9.98388	9.44348	10.55652
32	9.39958	9.98588	9.41370	10.58630	28	9.42781	9.98384	9.44397	10.55603
33	9.40006	9.98584	9.41422	10.58578	27	9.42826	9.98381	9.44446	10.55554
34	9.40055	9.98581	9.41474	10.58526	26	9.42872	9.98377	9.44495	10.55505
35	9.40103	9.98578	9.41526	10.58474	25	9.42917	9.98373	9.44544	10.55456
36	9.40152	9.98574	9.41578	10.58422	24	9.42962	9.98370	9.44592	10.55408
37	9.40200	9.98571	9.41629	10.58371	23	9.43007	9.98366	9.44641	10.55359
38	9.40249	9.98568	9.41681	10.58319	22	9.43053	9.98363	9.44690	10.55310
39	9.40297	9.98565	9.41733	10.58267	21	9.43098	9.98359	9.44738	10.55262
40	9.40346	9.98561	9.41784	10.58216	20	9.43143	9.98356	9.44787	10.55213
41	9.40394	9.98558	9.41836	10.58164	19	9.43188	9.98352	9.44836	10.55164
42	9.40442	9.98555	9.41887	10.58113	18	9.43233	9.98349	9.44884	10.55116
43	9.40490	9.98551	9.41939	10.58061	17	9.43278	9.98345	9.44933	10.55067
44	9.40538	9.98548	9.41990	10.58010	16	9.43323	9.98342	9.44981	10.55019
45	9.40586	9.98545	9.42041	10.57959	15	9.43367	9.98338	9.45029	10.54971
46	9.40634	9.98541	9.42093	10.57907	14	9.43412	9.98334	9.45078	10.54922
47	9.40682	9.98538	9.42144	10.57856	13	9.43457	9.98331	9.45126	10.54874
48	9.40730	9.98535	9.42195	10.57805	12	9.43502	9.98327	9.45174	10.54826
49	9.40778	9.98531	9.42246	10.57754	11	9.43546	9.98324	9.45222	10.54778
50	9.40825	9.98528	9.42297	10.57703	10	9.43591	9.98320	9.45271	10.54729
51	9.40873	9.98525	9.42348	10.57652	9	9.43635	9.98317	9.45319	10.54681
52	9.40921	9.98521	9.42399	10.57601	8	9.43680	9.98313	9.45367	10.54633
53	9.40968	9.98518	9.42450	10.57550	7	9.43724	9.98309	9.45415	10.54585
54	9.41016	9.98515	9.42501	10.57499	6	9.43769	9.98306	9.45463	10.54537
55	9.41063	9.98511	9.42552	10.57448	5	9.43813	9.98302	9.45511	10.54489
56	9.41111	9.98508	9.42603	10.57397	4	9.43857	9.98299	9.45559	10.54441
57	9.41158	9.98505	9.42653	10.57347	3	9.43901	9.98295	9.45606	10.54394
58	9.41205	9.98501	9.42704	10.57296	2	9.43946	9.98291	9.45654	10.54346
59	9.41252	9.98498	9.42755	10.57245	1	9.43990	9.98288	9.45702	10.54298
60	9.41300	9.98494	9.42805	10.57195	0	9.44034	9.98284	9.45750	10.54250
Co-sine	Sine	Co-tan.	Tangent	M	Co-sine	Sine	Co-tan.	Tangent.	M

378 TABLE OF SINES AND TANGENTS. 145.

16 Degrees.					17 Degrees.				
M	Sine.	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9.44034	9.98284	9.45750	10.54250	60	9.46504	9.98060	9.48534	10.51466
1	9.44078	9.98281	9.45797	10.54203	59	9.46635	9.98056	9.48579	10.51421
2	9.44122	9.98277	9.45845	10.54155	58	9.46766	9.98052	9.48624	10.51376
3	9.44166	9.98273	9.45892	10.54108	57	9.46717	9.98048	9.48669	10.51331
4	9.44210	9.98270	9.45940	10.54060	56	9.46758	9.98044	9.48714	10.51286
5	9.44253	9.98266	9.45987	10.54013	55	9.46800	9.98040	9.48759	10.51241
6	9.44297	9.98262	9.46035	10.53965	54	9.46841	9.98036	9.48804	10.51196
7	9.44341	9.98259	9.46082	10.53918	53	9.46882	9.98032	9.48849	10.51151
8	9.44385	9.98255	9.46130	10.53870	52	9.46923	9.98029	9.48894	10.51106
9	9.44428	9.98251	9.46177	10.53823	51	9.46964	9.98025	9.48939	10.51061
10	9.44472	9.98248	9.46224	10.53776	50	9.47005	9.98021	9.48984	10.51016
11	9.44516	9.98244	9.46271	10.53729	49	9.47045	9.98017	9.49029	10.50971
12	9.44559	9.98240	9.46319	10.53681	48	9.47086	9.98013	9.49073	10.50927
13	9.44602	9.98237	9.46366	10.53634	47	9.47127	9.98009	9.49118	10.50882
14	9.44646	9.98233	9.46413	10.53587	46	9.47168	9.98005	9.49163	10.50837
15	9.44689	9.98229	9.46460	10.53540	45	9.47209	9.98001	9.49207	10.50793
16	9.44733	9.98226	9.46507	10.53493	44	9.47249	9.97997	9.49252	10.50748
17	9.44776	9.98222	9.46554	10.53446	43	9.47290	9.97993	9.49296	10.50704
18	9.44819	9.98218	9.46601	10.53399	42	9.47330	9.97989	9.49341	10.50659
19	9.44862	9.98215	9.46648	10.53352	41	9.47371	9.97986	9.49385	10.50615
20	9.44905	9.98211	9.46694	10.53306	40	9.47411	9.97982	9.49430	10.50570
21	9.44948	9.98207	9.46741	10.53259	39	9.47452	9.97978	9.49474	10.50526
22	9.44992	9.98204	9.46788	10.53212	38	9.47492	9.97974	9.49519	10.50481
23	9.45035	9.98200	9.46835	10.53165	37	9.47533	9.97970	9.49563	10.50437
24	9.45077	9.98196	9.46881	10.53119	36	9.47573	9.97966	9.49607	10.50393
25	9.45120	9.98192	9.46928	10.53072	35	9.47613	9.97962	9.49652	10.50348
26	9.45163	9.98189	9.46975	10.53025	34	9.47654	9.97958	9.49696	10.50304
27	9.45206	9.98185	9.47021	10.52979	33	9.47694	9.97954	9.49740	10.50260
28	9.45249	9.98181	9.47068	10.52932	32	9.47734	9.97950	9.49784	10.50216
29	9.45292	9.98177	9.47114	10.52886	31	9.47774	9.97946	9.49828	10.50172
30	9.45334	9.98174	9.47160	10.52840	30	9.47814	9.97942	9.49872	10.50128
31	9.45377	9.98170	9.47207	10.52793	29	9.47854	9.97938	9.49916	10.50084
32	9.45419	9.98166	9.47253	10.52747	28	9.47894	9.97934	9.49960	10.50040
33	9.45462	9.98162	9.47299	10.52701	27	9.47934	9.97930	9.50004	10.49996
34	9.45504	9.98159	9.47346	10.52654	26	9.47974	9.97926	9.50048	10.49952
35	9.45547	9.98155	9.47392	10.52608	25	9.48014	9.97922	9.50092	10.49908
36	9.45589	9.98151	9.47438	10.52562	24	9.48054	9.97918	9.50136	10.49864
37	9.45632	9.98147	9.47484	10.52516	23	9.48094	9.97914	9.50180	10.49820
38	9.45674	9.98144	9.47530	10.52470	22	9.48133	9.97910	9.50223	10.49777
39	9.45716	9.98140	9.47576	10.52424	21	9.48173	9.97906	9.50267	10.49733
40	9.45758	9.98136	9.47622	10.52378	20	9.48213	9.97902	9.50311	10.49689
41	9.45801	9.98132	9.47668	10.52332	19	9.48252	9.97898	9.50355	10.49645
42	9.45843	9.98128	9.47714	10.52286	18	9.48292	9.97894	9.50398	10.49602
43	9.45885	9.98125	9.47760	10.52240	17	9.48332	9.97890	9.50442	10.49558
44	9.45927	9.98121	9.47806	10.52194	16	9.48371	9.97886	9.50485	10.49515
45	9.45969	9.98117	9.47852	10.52148	15	9.48411	9.97882	9.50529	10.49471
46	9.46011	9.98113	9.47897	10.52103	14	9.48450	9.97878	9.50572	10.49428
47	9.46053	9.98109	9.47943	10.52057	13	9.48490	9.97874	9.50616	10.49384
48	9.46095	9.98106	9.47989	10.52011	12	9.48529	9.97870	9.50659	10.49341
49	9.46136	9.98102	9.48035	10.51965	11	9.48568	9.97866	9.50703	10.49297
50	9.46178	9.98098	9.48080	10.51920	10	9.48607	9.97861	9.50746	10.49254
51	9.46220	9.98094	9.48126	10.51874	9	9.48647	9.97857	9.50789	10.49211
52	9.46262	9.98090	9.48171	10.51829	8	9.48686	9.97853	9.50833	10.49167
53	9.46303	9.98087	9.48217	10.51783	7	9.48725	9.97849	9.50876	10.49124
54	9.46345	9.98083	9.48262	10.51738	6	9.48764	9.97845	9.50919	10.49081
55	9.46386	9.98079	9.48307	10.51692	5	9.48803	9.97841	9.50962	10.49038
56	9.46428	9.98075	9.48353	10.51647	4	9.48842	9.97837	9.51005	10.48995
57	9.46469	9.98071	9.48398	10.51602	3	9.48881	9.97833	9.51048	10.48952
58	9.46511	9.98067	9.48443	10.51557	2	9.48920	9.97829	9.51092	10.48908
59	9.46552	9.98063	9.48489	10.51511	1	9.48959	9.97825	9.51135	10.48865
60	9.46594	9.98060	9.48534	10.51466	0	9.48998	9.97821	9.51178	10.48822
73 Degrees.					72 Degrees.				
Co-sine	Sine	Co-tan.	Tangent.	M	Co-sine	Sine	Co-tan.	Tangent.	M

18 Degrees.					19 Degrees.				
A	Sine	Co-fine	Tang.	Co-tang.	M	Sine	Co-fine	Tang.	Co-tang.
0	9,48998	9,97821	9,51178	10,48822	60	9,51264	9,97557	9,53697	10,46303
1	9,49037	9,97817	9,51221	10,48779	59	9,51301	9,97563	9,53738	10,46262
2	9,49076	9,97812	9,51264	10,48736	58	9,51337	9,97558	9,53779	10,46221
3	9,49115	9,97808	9,51306	10,48694	57	9,51374	9,97554	9,53820	10,46180
4	9,49153	9,97804	9,51349	10,48651	56	9,51411	9,97550	9,53861	10,46139
5	9,49192	9,97800	9,51392	10,48608	55	9,51447	9,97545	9,53902	10,46098
6	9,49231	9,97796	9,51435	10,48565	54	9,51484	9,97541	9,53943	10,46057
7	9,49269	9,97792	9,51478	10,48522	53	9,51520	9,97536	9,53984	10,46016
8	9,49308	9,97788	9,51520	10,48480	52	9,51557	9,97532	9,54025	10,45975
9	9,49347	9,97784	9,51563	10,48437	51	9,51593	9,97528	9,54065	10,45935
10	9,49385	9,97779	9,51606	10,48394	50	9,51629	9,97523	9,54106	10,45894
11	9,49424	9,97775	9,51648	10,48352	49	9,51666	9,97519	9,54147	10,45853
12	9,49462	9,97771	9,51691	10,48309	48	9,51702	9,97515	9,54187	10,45813
13	9,49500	9,97767	9,51734	10,48266	47	9,51738	9,97510	9,54228	10,45772
14	9,49539	9,97763	9,51776	10,48224	46	9,51774	9,97506	9,54269	10,45731
15	9,49577	9,97759	9,51819	10,48181	45	9,51811	9,97501	9,54309	10,45691
16	9,49615	9,97754	9,51861	10,48139	44	9,51847	9,97497	9,54350	10,45650
17	9,49654	9,97750	9,51903	10,48097	43	9,51883	9,97492	9,54390	10,45610
18	9,49692	9,97746	9,51946	10,48054	42	9,51919	9,97488	9,54431	10,45569
19	9,49730	9,97742	9,51988	10,48012	41	9,51955	9,97484	9,54471	10,45529
20	9,49768	9,97738	9,52031	10,47969	40	9,51991	9,97479	9,54512	10,45488
21	9,49806	9,97734	9,52073	10,47927	39	9,52027	9,97475	9,54552	10,45448
22	9,49844	9,97729	9,52115	10,47885	38	9,52063	9,97470	9,54593	10,45407
23	9,49882	9,97725	9,52157	10,47843	37	9,52099	9,97466	9,54633	10,45367
24	9,49920	9,97721	9,52199	10,47800	36	9,52135	9,97461	9,54673	10,45327
25	9,49958	9,97717	9,52242	10,47758	35	9,52171	9,97457	9,54714	10,45286
26	9,49996	9,97713	9,52284	10,47716	34	9,52207	9,97453	9,54754	10,45246
27	9,50034	9,97708	9,52326	10,47674	33	9,52242	9,97448	9,54794	10,45206
28	9,50072	9,97704	9,52368	10,47632	32	9,52278	9,97444	9,54835	10,45165
29	9,50110	9,97700	9,52410	10,47590	31	9,52314	9,97439	9,54875	10,45125
30	9,50148	9,97696	9,52452	10,47548	30	9,52350	9,97435	9,54915	10,45085
31	9,50185	9,97691	9,52494	10,47506	29	9,52385	9,97430	9,54955	10,45045
32	9,50223	9,97687	9,52536	10,47464	28	9,52421	9,97426	9,54995	10,45005
33	9,50261	9,97683	9,52578	10,47422	27	9,52456	9,97421	9,55035	10,44965
34	9,50298	9,97679	9,52620	10,47380	26	9,52492	9,97417	9,55075	10,44925
35	9,50336	9,97674	9,52661	10,47339	25	9,52527	9,97412	9,55115	10,44885
36	9,50374	9,97670	9,52703	10,47297	24	9,52563	9,97408	9,55155	10,44845
37	9,50411	9,97666	9,52745	10,47255	23	9,52598	9,97403	9,55195	10,44805
38	9,50449	9,97662	9,52787	10,47213	22	9,52634	9,97399	9,55235	10,44765
39	9,50486	9,97657	9,52829	10,47171	21	9,52669	9,97394	9,55275	10,44725
40	9,50523	9,97653	9,52870	10,47130	20	9,52705	9,97390	9,55315	10,44685
41	9,50561	9,97649	9,52912	10,47088	19	9,52740	9,97385	9,55355	10,44645
42	9,50598	9,97645	9,52953	10,47047	18	9,52775	9,97381	9,55395	10,44605
43	9,50635	9,97640	9,52995	10,47005	17	9,52811	9,97376	9,55434	10,44566
44	9,50673	9,97636	9,53037	10,46963	16	9,52846	9,97372	9,55474	10,44526
45	9,50710	9,97632	9,53078	10,46922	15	9,52881	9,97367	9,55514	10,44486
46	9,50747	9,97627	9,53120	10,46880	14	9,52916	9,97363	9,55554	10,44446
47	9,50784	9,97623	9,53161	10,46839	13	9,52951	9,97358	9,55593	10,44407
48	9,50821	9,97619	9,53202	10,46798	12	9,52986	9,97353	9,55633	10,44367
49	9,50858	9,97615	9,53244	10,46756	11	9,53021	9,97349	9,55673	10,44327
50	9,50896	9,97610	9,53285	10,46715	10	9,53056	9,97344	9,55712	10,44288
51	9,50933	9,97606	9,53327	10,46673	9	9,53092	9,97340	9,55752	10,44248
52	9,50970	9,97602	9,53368	10,46632	8	9,53126	9,97335	9,55791	10,44209
53	9,51007	9,97597	9,53409	10,46591	7	9,53161	9,97331	9,55831	10,44169
54	9,51043	9,97593	9,53450	10,46550	6	9,53196	9,97326	9,55870	10,44130
55	9,51080	9,97589	9,53492	10,46508	5	9,53231	9,97322	9,55910	10,44090
56	9,51117	9,97584	9,53533	10,46467	4	9,53266	9,97317	9,55949	10,44051
57	9,51154	9,97580	9,53574	10,46426	3	9,53301	9,97312	9,55989	10,44011
58	9,51191	9,97576	9,53615	10,46385	2	9,53336	9,97308	9,56028	10,43972
59	9,51227	9,97571	9,53656	10,46344	1	9,53370	9,97303	9,56067	10,43933
60	9,51264	9,97567	9,53697	10,46303	0	9,53405	9,97299	9,56107	10,43893
71 Degrees.					70 Degrees.				
Co-fine	Sine	Co-tan.	Tangent.	M	Co-fine	Sine	Co-tan.	Tangent.	M

20 Degrees.					21 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9.53405	9.97299	9.56107	10.43893	60	9.55433	9.97015	9.58418	10.41582
1	9.53440	9.97294	9.56146	10.43854	59	9.55466	9.97010	9.58455	10.41545
2	9.53475	9.97289	9.56185	10.43815	58	9.55499	9.97005	9.58493	10.41507
3	9.53509	9.97285	9.56224	10.43776	57	9.55532	9.97001	9.58531	10.41469
4	9.53544	9.97280	9.56264	10.43736	56	9.55564	9.96996	9.58569	10.41431
5	9.53578	9.97276	9.56303	10.43697	55	9.55597	9.96991	9.58606	10.41394
6	9.53613	9.97271	9.56342	10.43658	54	9.55630	9.96986	9.58644	10.41356
7	9.53647	9.97266	9.56381	10.43619	53	9.55663	9.96981	9.58681	10.41319
8	9.53682	9.97262	9.56420	10.43580	52	9.55695	9.96976	9.58719	10.41281
9	9.53716	9.97257	9.56459	10.43541	51	9.55728	9.96971	9.58757	10.41243
10	9.53751	9.97252	9.56498	10.43502	50	9.55761	9.96966	9.58794	10.41206
11	9.53785	9.97248	9.56537	10.43463	49	9.55793	9.96962	9.58832	10.41168
12	9.53819	9.97243	9.56576	10.43424	48	9.55826	9.96957	9.58869	10.41131
13	9.53854	9.97238	9.56615	10.43385	47	9.55858	9.96952	9.58907	10.41093
14	9.53888	9.97234	9.56654	10.43346	46	9.55891	9.96947	9.58944	10.41056
15	9.53922	9.97229	9.56693	10.43307	45	9.55923	9.96942	9.58981	10.41019
16	9.53957	9.97224	9.56732	10.43268	44	9.55956	9.96937	9.59019	10.40981
17	9.53991	9.97220	9.56771	10.43229	43	9.55988	9.96932	9.59056	10.40944
18	9.54025	9.97215	9.56810	10.43190	42	9.56021	9.96927	9.59094	10.40906
19	9.54059	9.97210	9.56849	10.43151	41	9.56053	9.96922	9.59131	10.40869
20	9.54093	9.97206	9.56887	10.43113	40	9.56085	9.96917	9.59168	10.40832
21	9.54127	9.97201	9.56926	10.43074	39	9.56118	9.96912	9.59205	10.40795
22	9.54161	9.97196	9.56965	10.43035	38	9.56150	9.96907	9.59243	10.40757
23	9.54195	9.97192	9.57004	10.42996	37	9.56182	9.96903	9.59280	10.40720
24	9.54229	9.97187	9.57042	10.42958	36	9.56215	9.96898	9.59317	10.40683
25	9.54263	9.97182	9.57081	10.42919	35	9.56247	9.96893	9.59354	10.40646
26	9.54297	9.97178	9.57120	10.42880	34	9.56279	9.96888	9.59391	10.40609
27	9.54331	9.97173	9.57158	10.42842	33	9.56311	9.96883	9.59429	10.40571
28	9.54365	9.97168	9.57197	10.42803	32	9.56343	9.96878	9.59466	10.40534
29	9.54399	9.97163	9.57235	10.42765	31	9.56375	9.96873	9.59503	10.40497
30	9.54433	9.97159	9.57274	10.42726	30	9.56408	9.96868	9.59540	10.40460
31	9.54466	9.97154	9.57312	10.42688	29	9.56440	9.96863	9.59577	10.40423
32	9.54500	9.97149	9.57351	10.42649	28	9.56472	9.96858	9.59614	10.40386
33	9.54534	9.97145	9.57389	10.42611	27	9.56504	9.96853	9.59651	10.40349
34	9.54567	9.97140	9.57428	10.42572	26	9.56536	9.96848	9.59688	10.40312
35	9.54601	9.97135	9.57466	10.42534	25	9.56568	9.96843	9.59725	10.40275
36	9.54635	9.97130	9.57504	10.42496	24	9.56599	9.96838	9.59762	10.40238
37	9.54668	9.97126	9.57543	10.42457	23	9.56631	9.96833	9.59799	10.40201
38	9.54702	9.97121	9.57581	10.42419	22	9.56663	9.96828	9.59835	10.40165
39	9.54735	9.97116	9.57619	10.42381	21	9.56695	9.96823	9.59872	10.40128
40	9.54769	9.97111	9.57658	10.42342	20	9.56727	9.96818	9.59909	10.40091
41	9.54802	9.97107	9.57696	10.42304	19	9.56759	9.96813	9.59946	10.40054
42	9.54836	9.97102	9.57734	10.42266	18	9.56790	9.96808	9.59983	10.40017
43	9.54869	9.97097	9.57772	10.42228	17	9.56822	9.96803	9.60019	10.39981
44	9.54903	9.97092	9.57810	10.42190	16	9.56854	9.96798	9.60056	10.39944
45	9.54936	9.97087	9.57849	10.42151	15	9.56886	9.96793	9.60093	10.39907
46	9.54969	9.97083	9.57887	10.42113	14	9.56917	9.96788	9.60130	10.39870
47	9.55003	9.97078	9.57925	10.42075	13	9.56949	9.96783	9.60166	10.39834
48	9.55036	9.97073	9.57963	10.42037	12	9.56980	9.96778	9.60203	10.39797
49	9.55069	9.97068	9.58001	10.41999	11	9.57012	9.96772	9.60240	10.39760
50	9.55102	9.97063	9.58039	10.41961	10	9.57044	9.96767	9.60276	10.39724
51	9.55136	9.97059	9.58077	10.41923	9	9.57075	9.96762	9.60313	10.39687
52	9.55169	9.97054	9.58115	10.41885	8	9.57107	9.96757	9.60349	10.39651
53	9.55202	9.97049	9.58153	10.41847	7	9.57138	9.96752	9.60386	10.39614
54	9.55235	9.97044	9.58191	10.41809	6	9.57169	9.96747	9.60422	10.39578
55	9.55268	9.97039	9.58229	10.41771	5	9.57201	9.96742	9.60459	10.39541
56	9.55301	9.97035	9.58267	10.41733	4	9.57232	9.96737	9.60495	10.39505
57	9.55334	9.97030	9.58304	10.41696	3	9.57264	9.96732	9.60532	10.39468
58	9.55367	9.97025	9.58342	10.41658	2	9.57295	9.96727	9.60568	10.39432
59	9.55400	9.97020	9.58380	10.41620	1	9.57326	9.96722	9.60605	10.39395
60	9.55433	9.97015	9.58418	10.41582	0	9.57358	9.96717	9.60641	10.39359
Co-sine	Sine	Co-tan.	Tangent	M	Co-sine	Sine	Co-tan.	Tangent	M
69 Degrees.					68 Degrees.				

TABLE OF SINES AND TANGENTS. 145. 381

22 Degrees.				23 Degrees.			
M	Sine	Co-fine	Tang.	M	Sine	Co-fine	Tang.
0	9,57358	9,96717	9,60641	10	9,59188	9,96403	9,62785
1	9,57389	9,96711	9,60677	11	9,59218	9,96397	9,62820
2	9,57420	9,96706	9,60714	12	9,59247	9,96392	9,62855
3	9,57451	9,96701	9,60750	13	9,59277	9,96386	9,62890
4	9,57482	9,96696	9,60786	14	9,59307	9,96381	9,62926
5	9,57514	9,96691	9,60823	15	9,59336	9,96376	9,62961
6	9,57545	9,96686	9,60859	16	9,59366	9,96370	9,62996
7	9,57576	9,96681	9,60895	17	9,59396	9,96365	9,63031
8	9,57607	9,96676	9,60931	18	9,59425	9,96360	9,63066
9	9,57638	9,96670	9,60967	19	9,59455	9,96354	9,63101
10	9,57669	9,96665	9,61004	20	9,59484	9,96349	9,63135
11	9,57700	9,96660	9,61040	21	9,59514	9,96343	9,63170
12	9,57731	9,96655	9,61076	22	9,59543	9,96338	9,63205
13	9,57762	9,96650	9,61112	23	9,59573	9,96333	9,63240
14	9,57793	9,96645	9,61148	24	9,59602	9,96327	9,63275
15	9,57824	9,96640	9,61184	25	9,59632	9,96322	9,63310
16	9,57854	9,96634	9,61220	26	9,59661	9,96316	9,63345
17	9,57885	9,96629	9,61256	27	9,59690	9,96311	9,63379
18	9,57916	9,96624	9,61292	28	9,59720	9,96305	9,63414
19	9,57947	9,96619	9,61328	29	9,59749	9,96300	9,63449
20	9,57978	9,96614	9,61364	30	9,59778	9,96294	9,63484
21	9,58008	9,96608	9,61400	31	9,59808	9,96289	9,63519
22	9,58039	9,96603	9,61436	32	9,59837	9,96284	9,63553
23	9,58070	9,96598	9,61472	33	9,59866	9,96278	9,63588
24	9,58101	9,96593	9,61508	34	9,59895	9,96273	9,63623
25	9,58131	9,96588	9,61544	35	9,59924	9,96267	9,63657
26	9,58162	9,96582	9,61579	36	9,59954	9,96262	9,63692
27	9,58192	9,96577	9,61615	37	9,59983	9,96256	9,63726
28	9,58223	9,96572	9,61651	38	9,60012	9,96251	9,63761
29	9,58253	9,96567	9,61687	39	9,60041	9,96245	9,63796
30	9,58284	9,96562	9,61722	40	9,60070	9,96240	9,63830
31	9,58314	9,96556	9,61758	41	9,60099	9,96234	9,63865
32	9,58345	9,96551	9,61794	42	9,60128	9,96229	9,63899
33	9,58375	9,96546	9,61830	43	9,60157	9,96223	9,63934
34	9,58406	9,96541	9,61865	44	9,60186	9,96218	9,63968
35	9,58436	9,96535	9,61901	45	9,60215	9,96212	9,64003
36	9,58467	9,96530	9,61936	46	9,60244	9,96207	9,64037
37	9,58497	9,96525	9,61972	47	9,60273	9,96201	9,64072
38	9,58527	9,96520	9,62008	48	9,60302	9,96196	9,64106
39	9,58557	9,96514	9,62043	49	9,60331	9,96190	9,64140
40	9,58588	9,96509	9,62079	50	9,60359	9,96185	9,64175
41	9,58618	9,96504	9,62114	51	9,60388	9,96179	9,64209
42	9,58648	9,96498	9,62150	52	9,60417	9,96174	9,64243
43	9,58678	9,96493	9,62185	53	9,60446	9,96168	9,64278
44	9,58709	9,96488	9,62221	54	9,60474	9,96162	9,64312
45	9,58739	9,96483	9,62256	55	9,60503	9,96157	9,64346
46	9,58769	9,96477	9,62292	56	9,60532	9,96151	9,64381
47	9,58799	9,96472	9,62327	57	9,60561	9,96146	9,64415
48	9,58829	9,96467	9,62362	58	9,60589	9,96140	9,64449
49	9,58859	9,96461	9,62398	59	9,60618	9,96135	9,64483
50	9,58889	9,96456	9,62433	60	9,60646	9,96129	9,64517
51	9,58919	9,96451	9,62468	51	9,60675	9,96123	9,64552
52	9,58949	9,96445	9,62504	52	9,60704	9,96118	9,64586
53	9,58979	9,96440	9,62539	53	9,60732	9,96112	9,64620
54	9,59009	9,96435	9,62574	54	9,60761	9,96107	9,64654
55	9,59039	9,96429	9,62609	55	9,60789	9,96101	9,64688
56	9,59069	9,96424	9,62645	56	9,60818	9,96095	9,64722
57	9,59098	9,96419	9,62680	57	9,60846	9,96090	9,64756
58	9,59128	9,96413	9,62715	58	9,60875	9,96084	9,64790
59	9,59158	9,96408	9,62750	59	9,60903	9,96079	9,64824
60	9,59188	9,96403	9,62785	60	9,60931	9,96073	9,64858
Co-fine	Sine	Co-tan	Tangent.	Co-fine	Sine	Co-tan	Tangent.

67 Degrees.

66 Degrees.

382 TABLE OF SINES AND TANGENTS. 145.

24 Degrees.					25 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9,60931	9,96073	9,64858	10,35142	60	0,9,62595	9,95728	9,66867	10,33133
1	9,60960	9,96067	9,64892	10,35108	59	1,9,62622	9,95722	9,66900	10,33100
2	9,60988	9,96062	9,64926	10,35074	58	2,9,62649	9,95716	9,66933	10,33067
3	9,61016	9,96056	9,64960	10,35040	57	3,9,62676	9,95710	9,66966	10,33034
4	9,61045	9,96050	9,64994	10,35006	56	4,9,62703	9,95704	9,66999	10,33001
5	9,61073	9,96045	9,65028	10,34972	55	5,9,62730	9,95698	9,67032	10,32968
6	9,61101	9,96039	9,65062	10,34938	54	6,9,62757	9,95692	9,67065	10,32935
7	9,61129	9,96034	9,65096	10,34904	53	7,9,62784	9,95686	9,67098	10,32902
8	9,61158	9,96028	9,65130	10,34870	52	8,9,62811	9,95680	9,67131	10,32869
9	9,61186	9,96022	9,65164	10,34836	51	9,9,62838	9,95674	9,67163	10,32837
10	9,61214	9,96017	9,65197	10,34803	50	10,9,62865	9,95668	9,67196	10,32804
11	9,61242	9,96011	9,65231	10,34769	49	11,9,62892	9,95662	9,67229	10,32771
12	9,61270	9,96005	9,65265	10,34735	48	12,9,62918	9,95657	9,67262	10,32738
13	9,61298	9,96000	9,65299	10,34701	47	13,9,62945	9,95651	9,67295	10,32705
14	9,61326	9,95994	9,65333	10,34667	46	14,9,62972	9,95645	9,67327	10,32673
15	9,61354	9,95988	9,65366	10,34634	45	15,9,62999	9,95639	9,67360	10,32640
16	9,61382	9,95982	9,65400	10,34600	44	16,9,63026	9,95633	9,67393	10,32607
17	9,61411	9,95977	9,65434	10,34566	43	17,9,63052	9,95627	9,67426	10,32574
18	9,61438	9,95971	9,65467	10,34533	42	18,9,63079	9,95621	9,67458	10,32542
19	9,61466	9,95965	9,65501	10,34499	41	19,9,63106	9,95615	9,67491	10,32509
20	9,61494	9,95960	9,65535	10,34465	40	20,9,63133	9,95609	9,67524	10,32476
21	9,61522	9,95954	9,65568	10,34432	39	21,9,63159	9,95603	9,67556	10,32444
22	9,61550	9,95948	9,65602	10,34398	38	22,9,63186	9,95597	9,67589	10,32411
23	9,61578	9,95942	9,65636	10,34364	37	23,9,63213	9,95591	9,67622	10,32378
24	9,61606	9,95937	9,65669	10,34331	36	24,9,63239	9,95585	9,67654	10,32346
25	9,61634	9,95931	9,65703	10,34297	35	25,9,63266	9,95579	9,67687	10,32313
26	9,61662	9,95925	9,65736	10,34264	34	26,9,63292	9,95573	9,67719	10,32281
27	9,61689	9,95920	9,65770	10,34230	33	27,9,63319	9,95567	9,67752	10,32248
28	9,61717	9,95914	9,65803	10,34197	32	28,9,63345	9,95561	9,67785	10,32215
29	9,61745	9,95908	9,65837	10,34163	31	29,9,63372	9,95555	9,67817	10,32183
30	9,61773	9,95902	9,65870	10,34130	30	30,9,63398	9,95549	9,67850	10,32150
31	9,61800	9,95897	9,65904	10,34096	29	31,9,63425	9,95543	9,67882	10,32118
32	9,61828	9,95891	9,65937	10,34063	28	32,9,63451	9,95537	9,67915	10,32085
33	9,61856	9,95885	9,65971	10,34029	27	33,9,63478	9,95531	9,67947	10,32053
34	9,61883	9,95879	9,66004	10,33996	26	34,9,63504	9,95525	9,67980	10,32020
35	9,61911	9,95873	9,66038	10,33962	25	35,9,63531	9,95519	9,68012	10,31988
36	9,61939	9,95868	9,66071	10,33929	24	36,9,63557	9,95513	9,68044	10,31956
37	9,61966	9,95862	9,66104	10,33896	23	37,9,63583	9,95507	9,68077	10,31923
38	9,61994	9,95856	9,66138	10,33862	22	38,9,63610	9,95500	9,68109	10,31891
39	9,62021	9,95850	9,66171	10,33829	21	39,9,63636	9,95494	9,68142	10,31858
40	9,62049	9,95844	9,66204	10,33796	20	40,9,63662	9,95488	9,68174	10,31826
41	9,62076	9,95839	9,66238	10,33762	19	41,9,63689	9,95482	9,68206	10,31794
42	9,62104	9,95833	9,66271	10,33729	18	42,9,63715	9,95476	9,68239	10,31761
43	9,62131	9,95827	9,66304	10,33696	17	43,9,63741	9,95470	9,68271	10,31729
44	9,62159	9,95821	9,66337	10,33663	16	44,9,63767	9,95464	9,68303	10,31697
45	9,62186	9,95815	9,66371	10,33629	15	45,9,63794	9,95458	9,68336	10,31664
46	9,62214	9,95810	9,66404	10,33596	14	46,9,63820	9,95452	9,68368	10,31632
47	9,62241	9,95804	9,66437	10,33563	13	47,9,63846	9,95446	9,68400	10,31600
48	9,62268	9,95798	9,66470	10,33530	12	48,9,63872	9,95440	9,68432	10,31568
49	9,62296	9,95792	9,66503	10,33497	11	49,9,63898	9,95434	9,68465	10,31535
50	9,62323	9,95786	9,66537	10,33463	10	50,9,63924	9,95427	9,68497	10,31503
51	9,62350	9,95780	9,66570	10,33430	9	51,9,63950	9,95421	9,68529	10,31471
52	9,62377	9,95775	9,66603	10,33397	8	52,9,63976	9,95415	9,68561	10,31439
53	9,62405	9,95769	9,66636	10,33364	7	53,9,64002	9,95409	9,68593	10,31407
54	9,62432	9,95763	9,66669	10,33331	6	54,9,64028	9,95403	9,68626	10,31374
55	9,62459	9,95757	9,66702	10,33298	5	55,9,64054	9,95397	9,68658	10,31342
56	9,62486	9,95751	9,66735	10,33265	4	56,9,64080	9,95391	9,68690	10,31310
57	9,62513	9,95745	9,66768	10,33232	3	57,9,64106	9,95384	9,68722	10,31278
58	9,62541	9,95739	9,66801	10,33199	2	58,9,64132	9,95378	9,68754	10,31246
59	9,62568	9,95733	9,66834	10,33166	1	59,9,64158	9,95372	9,68786	10,31214
60	9,62595	9,95728	9,66867	10,33133	0	60,9,64184	9,95366	9,68818	10,31182
Co-sine Sine Co-tan. Tangent M					Co-sine Sine Co-tan. Tangent M				
65 Degrees.					64 Degrees.				

TABLE OF SINES AND TANGENTS. 145. 383

26 Degrees.					27 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9,64184	9,95366	9,68818	10,31182	60	9,65705	9,94988	9,70717	10,29283
1	9,64210	9,95360	9,68850	10,31150	59	9,65729	9,94982	9,70748	10,29252
2	9,64236	9,95354	9,68882	10,31118	58	9,65754	9,94975	9,70779	10,29221
3	9,64262	9,95348	9,68914	10,31086	57	9,65779	9,94969	9,70810	10,29190
4	9,64288	9,95341	9,68946	10,31054	56	9,65804	9,94962	9,70841	10,29159
5	9,64313	9,95335	9,68978	10,31022	55	9,65828	9,94956	9,70873	10,29127
6	9,64339	9,95329	9,69010	10,30990	54	9,65853	9,94949	9,70904	10,29096
7	9,64365	9,95323	9,69042	10,30958	53	9,65878	9,94943	9,70935	10,29065
8	9,64391	9,95317	9,69074	10,30926	52	9,65902	9,94936	9,70966	10,29034
9	9,64417	9,95310	9,69106	10,30894	51	9,65927	9,94930	9,70997	10,29003
10	9,64442	9,95304	9,69138	10,30862	50	9,65952	9,94923	9,71028	10,28972
11	9,64468	9,95298	9,69170	10,30830	49	9,65976	9,94917	9,71059	10,28941
12	9,64494	9,95292	9,69202	10,30798	48	9,66001	9,94911	9,71090	10,28910
13	9,64519	9,95286	9,69234	10,30766	47	9,66025	9,94904	9,71121	10,28879
14	9,64545	9,95279	9,69266	10,30734	46	9,66050	9,94898	9,71153	10,28847
15	9,64571	9,95273	9,69298	10,30702	45	9,66075	9,94891	9,71184	10,28816
16	9,64596	9,95267	9,69329	10,30671	44	9,66099	9,94884	9,71215	10,28785
17	9,64622	9,95261	9,69361	10,30639	43	9,66124	9,94878	9,71246	10,28754
18	9,64647	9,95254	9,69393	10,30607	42	9,66148	9,94871	9,71277	10,28723
19	9,64673	9,95248	9,69425	10,30575	41	9,66173	9,94865	9,71308	10,28692
20	9,64698	9,95242	9,69457	10,30543	40	9,66197	9,94858	9,71339	10,28661
21	9,64724	9,95236	9,69488	10,30512	39	9,66221	9,94852	9,71370	10,28630
22	9,64749	9,95229	9,69520	10,30480	38	9,66246	9,94845	9,71401	10,28599
23	9,64775	9,95223	9,69552	10,30448	37	9,66270	9,94839	9,71431	10,28569
24	9,64800	9,95217	9,69584	10,30416	36	9,66295	9,94832	9,71462	10,28538
25	9,64826	9,95211	9,69615	10,30385	35	9,66319	9,94826	9,71493	10,28507
26	9,64851	9,95204	9,69647	10,30353	34	9,66343	9,94819	9,71524	10,28476
27	9,64877	9,95198	9,69679	10,30321	33	9,66368	9,94813	9,71555	10,28445
28	9,64902	9,95192	9,69710	10,30290	32	9,66392	9,94806	9,71586	10,28414
29	9,64927	9,95185	9,69742	10,30258	31	9,66416	9,94799	9,71617	10,28383
30	9,64953	9,95179	9,69774	10,30226	30	9,66441	9,94793	9,71648	10,28352
31	9,64978	9,95173	9,69805	10,30195	29	9,66465	9,94786	9,71679	10,28321
32	9,65003	9,95167	9,69837	10,30163	28	9,66489	9,94780	9,71709	10,28291
33	9,65029	9,95160	9,69868	10,30132	27	9,66513	9,94773	9,71740	10,28260
34	9,65054	9,95154	9,69900	10,30100	26	9,66537	9,94767	9,71771	10,28229
35	9,65079	9,95148	9,69932	10,30068	25	9,66562	9,94760	9,71802	10,28198
36	9,65104	9,95141	9,69963	10,30037	24	9,66586	9,94753	9,71833	10,28167
37	9,65130	9,95135	9,69995	10,30005	23	9,66610	9,94747	9,71863	10,28137
38	9,65155	9,95129	9,70026	10,29974	22	9,66634	9,94740	9,71894	10,28106
39	9,65180	9,95122	9,70058	10,29942	21	9,66658	9,94734	9,71925	10,28075
40	9,65205	9,95116	9,70089	10,29911	20	9,66682	9,94727	9,71955	10,28045
41	9,65230	9,95110	9,70121	10,29879	19	9,66706	9,94720	9,71986	10,28014
42	9,65255	9,95103	9,70152	10,29848	18	9,66731	9,94714	9,72017	10,27983
43	9,65281	9,95097	9,70184	10,29816	17	9,66755	9,94707	9,72048	10,27952
44	9,65306	9,95090	9,70215	10,29785	16	9,66779	9,94700	9,72078	10,27922
45	9,65331	9,95084	9,70247	10,29753	15	9,66803	9,94694	9,72109	10,27891
46	9,65356	9,95078	9,70278	10,29722	14	9,66827	9,94687	9,72140	10,27860
47	9,65381	9,95071	9,70309	10,29691	13	9,66851	9,94680	9,72170	10,27830
48	9,65406	9,95065	9,70341	10,29659	12	9,66875	9,94674	9,72201	10,27799
49	9,65431	9,95059	9,70372	10,29628	11	9,66899	9,94667	9,72231	10,27769
50	9,65456	9,95052	9,70404	10,29596	10	9,66922	9,94660	9,72262	10,27738
51	9,65481	9,95046	9,70435	10,29565	9	9,66946	9,94654	9,72293	10,27707
52	9,65506	9,95039	9,70466	10,29534	8	9,66970	9,94647	9,72323	10,27677
53	9,65531	9,95033	9,70498	10,29502	7	9,66994	9,94640	9,72354	10,27646
54	9,65556	9,95027	9,70529	10,29471	6	9,67018	9,94634	9,72384	10,27616
55	9,65580	9,95020	9,70560	10,29440	5	9,67042	9,94627	9,72415	10,27585
56	9,65605	9,95014	9,70592	10,29408	4	9,67066	9,94620	9,72445	10,27555
57	9,65630	9,95007	9,70623	10,29377	3	9,67090	9,94614	9,72476	10,27524
58	9,65655	9,95001	9,70654	10,29346	2	9,67113	9,94607	9,72506	10,27494
59	9,65680	9,94995	9,70685	10,29315	1	9,67137	9,94600	9,72537	10,27463
60	9,65705	9,94988	9,70717	10,29283	0	9,67161	9,94593	9,72567	10,27433
Co-sine Sine Co-tan. Tangent M					Co-sine Sine Co-tan. Tangent. M				
63 Degrees.					62 Degrees.				

384 TABLE OF SINES AND TANGENTS. 145.

28 Degrees.					29 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9,67161	9,94593	9,72567	10,27433	60	9,68557	9,94182	9,74375	10,25625
1	9,67185	9,94587	9,72598	10,27402	59	9,68580	9,94175	9,74405	10,25595
2	9,67208	9,94580	9,72628	10,27372	58	9,68603	9,94168	9,74435	10,25565
3	9,67232	9,94573	9,72659	10,27341	57	9,68625	9,94161	9,74465	10,25535
4	9,67256	9,94567	9,72689	10,27311	56	9,68648	9,94154	9,74494	10,25506
5	9,67280	9,94560	9,72720	10,27280	55	9,68671	9,94147	9,74524	10,25476
6	9,67303	9,94553	9,72750	10,27250	54	9,68694	9,94140	9,74554	10,25446
7	9,67327	9,94546	9,72780	10,27220	53	9,68716	9,94133	9,74583	10,25417
8	9,67350	9,94540	9,72811	10,27189	52	9,68739	9,94126	9,74613	10,25387
9	9,67374	9,94533	9,72841	10,27159	51	9,68762	9,94119	9,74643	10,25357
10	9,67398	9,94526	9,72872	10,27128	50	9,68784	9,94112	9,74673	10,25337
11	9,67421	9,94519	9,72902	10,27098	49	9,68807	9,94105	9,74702	10,25298
12	9,67445	9,94513	9,72932	10,27068	48	9,68829	9,94098	9,74732	10,25268
13	9,67468	9,94506	9,72963	10,27037	47	9,68852	9,94090	9,74762	10,25238
14	9,67492	9,94499	9,72993	10,27007	46	9,68875	9,94083	9,74791	10,25209
15	9,67515	9,94492	9,73023	10,26977	45	9,68897	9,94076	9,74821	10,25179
16	9,67539	9,94485	9,73054	10,26946	44	9,68920	9,94069	9,74851	10,25149
17	9,67562	9,94479	9,73084	10,26916	43	9,68942	9,94062	9,74880	10,25120
18	9,67586	9,94472	9,73114	10,26886	42	9,68965	9,94055	9,74910	10,25090
19	9,67609	9,94465	9,73144	10,26856	41	9,68987	9,94048	9,74939	10,25061
20	9,67633	9,94458	9,73175	10,26825	40	9,69010	9,94041	9,74969	10,25031
21	9,67656	9,94451	9,73205	10,26795	39	9,69032	9,94034	9,74998	10,25002
22	9,67680	9,94445	9,73235	10,26765	38	9,69055	9,94027	9,75028	10,24972
23	9,67703	9,94438	9,73265	10,26735	37	9,69077	9,94020	9,75058	10,24942
24	9,67726	9,94431	9,73295	10,26705	36	9,69100	9,94012	9,75087	10,24913
25	9,67750	9,94424	9,73326	10,26674	35	9,69122	9,94005	9,75117	10,24883
26	9,67773	9,94417	9,73356	10,26644	34	9,69144	9,93998	9,75146	10,24854
27	9,67796	9,94410	9,73386	10,26614	33	9,69167	9,93991	9,75176	10,24824
28	9,67820	9,94404	9,73416	10,26584	32	9,69189	9,93984	9,75205	10,24795
29	9,67843	9,94397	9,73446	10,26554	31	9,69212	9,93977	9,75235	10,24765
30	9,67866	9,94390	9,73476	10,26524	30	9,69234	9,93970	9,75264	10,24736
31	9,67890	9,94383	9,73507	10,26493	29	9,69256	9,93963	9,75294	10,24706
32	9,67913	9,94376	9,73537	10,26463	28	9,69279	9,93955	9,75323	10,24677
33	9,67936	9,94369	9,73567	10,26433	27	9,69301	9,93948	9,75353	10,24647
34	9,67959	9,94362	9,73597	10,26403	26	9,69323	9,93941	9,75382	10,24618
35	9,67982	9,94355	9,73627	10,26373	25	9,69345	9,93934	9,75411	10,24589
36	9,68006	9,94349	9,73657	10,26343	24	9,69368	9,93927	9,75441	10,24559
37	9,68029	9,94342	9,73687	10,26313	23	9,69390	9,93920	9,75470	10,24530
38	9,68052	9,94335	9,73717	10,26283	22	9,69412	9,93912	9,75500	10,24500
39	9,68075	9,94328	9,73747	10,26253	21	9,69434	9,93905	9,75529	10,24471
40	9,68098	9,94321	9,73777	10,26223	20	9,69456	9,93898	9,75558	10,24442
41	9,68121	9,94314	9,73807	10,26193	19	9,69479	9,93891	9,75588	10,24412
42	9,68144	9,94307	9,73837	10,26163	18	9,69501	9,93884	9,75617	10,24383
43	9,68167	9,94300	9,73867	10,26133	17	9,69523	9,93876	9,75647	10,24353
44	9,68190	9,94293	9,73897	10,26103	16	9,69545	9,93869	9,75676	10,24324
45	9,68213	9,94286	9,73927	10,26073	15	9,69567	9,93862	9,75705	10,24295
46	9,68237	9,94279	9,73957	10,26043	14	9,69589	9,93855	9,75735	10,24265
47	9,68260	9,94273	9,73987	10,26013	13	9,69611	9,93847	9,75764	10,24236
48	9,68282	9,94266	9,74017	10,25983	12	9,69633	9,93840	9,75793	10,24207
49	9,68305	9,94259	9,74047	10,25953	11	9,69655	9,93833	9,75822	10,24178
50	9,68328	9,94252	9,74077	10,25923	10	9,69677	9,93826	9,75852	10,24148
51	9,68351	9,94245	9,74107	10,25893	9	9,69699	9,93819	9,75881	10,24119
52	9,68374	9,94238	9,74137	10,25863	8	9,69721	9,93811	9,75910	10,24090
53	9,68397	9,94231	9,74166	10,25834	7	9,69743	9,93804	9,75939	10,24061
54	9,68420	9,94224	9,74196	10,25804	6	9,69765	9,93797	9,75969	10,24031
55	9,68443	9,94217	9,74226	10,25774	5	9,69787	9,93789	9,75998	10,24002
56	9,68466	9,94210	9,74256	10,25744	4	9,69809	9,93782	9,76027	10,23973
57	9,68489	9,94203	9,74286	10,25714	3	9,69831	9,93775	9,76056	10,23944
58	9,68512	9,94196	9,74316	10,25684	2	9,69853	9,93768	9,76086	10,23914
59	9,68534	9,94189	9,74345	10,25655	1	9,69875	9,93760	9,76115	10,23885
60	9,68557	9,94182	9,74375	10,25625	0	9,69897	9,93753	9,76144	10,23856
Co-sine	Sine	Co-tan.	Tangent.	M	Co-sine	Sine	Co-tan.	Tangent.	M
61 Degrees.					60 Degrees.				

TABLE OF SINES AND TANGENTS. 145. 385

30 Degrees.					31 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9,69897	9,93753	9,76144	10,23856	60	9,71184	9,93307	9,77877	10,22123
1	9,69919	9,93746	9,76173	10,23827	59	9,71205	9,93299	9,77906	10,22094
2	9,69941	9,93738	9,76202	10,23798	58	9,71226	9,93291	9,77935	10,22065
3	9,69963	9,93731	9,76231	10,23769	57	9,71247	9,93284	9,77963	10,22037
4	9,69984	9,93724	9,76261	10,23739	56	9,71268	9,93276	9,77992	10,22008
5	9,70006	9,93717	9,76290	10,23710	55	9,71289	9,93269	9,78020	10,21980
6	9,70028	9,93709	9,76319	10,23681	54	9,71310	9,93261	9,78049	10,21951
7	9,70050	9,93702	9,76348	10,23652	53	9,71331	9,93253	9,78077	10,21923
8	9,70072	9,93695	9,76377	10,23623	52	9,71352	9,93246	9,78106	10,21894
9	9,70093	9,93687	9,76406	10,23594	51	9,71373	9,93238	9,78135	10,21865
10	9,70115	9,93680	9,76435	10,23565	50	9,71393	9,93230	9,78163	10,21837
11	9,70137	9,93673	9,76464	10,23536	49	9,71414	9,93223	9,78192	10,21808
12	9,70159	9,93665	9,76493	10,23507	48	9,71435	9,93215	9,78220	10,21780
13	9,70180	9,93658	9,76522	10,23478	47	9,71456	9,93207	9,78249	10,21751
14	9,70202	9,93650	9,76551	10,23449	46	9,71477	9,93200	9,78277	10,21723
15	9,70224	9,93643	9,76580	10,23420	45	9,71498	9,93192	9,78306	10,21694
16	9,70245	9,93636	9,76609	10,23391	44	9,71519	9,93184	9,78334	10,21666
17	9,70267	9,93628	9,76639	10,23361	43	9,71539	9,93177	9,78363	10,21637
18	9,70288	9,93621	9,76668	10,23332	42	9,71560	9,93169	9,78391	10,21609
19	9,70310	9,93614	9,76697	10,23303	41	9,71581	9,93161	9,78419	10,21581
20	9,70332	9,93606	9,76725	10,23275	40	9,71602	9,93154	9,78448	10,21552
21	9,70353	9,93599	9,76754	10,23246	39	9,71622	9,93146	9,78476	10,21524
22	9,70375	9,93591	9,76783	10,23217	38	9,71643	9,93138	9,78505	10,21495
23	9,70396	9,93584	9,76812	10,23188	37	9,71664	9,93131	9,78533	10,21467
24	9,70418	9,93577	9,76841	10,23159	36	9,71685	9,93123	9,78562	10,21438
25	9,70439	9,93569	9,76870	10,23130	35	9,71705	9,93115	9,78590	10,21410
26	9,70461	9,93562	9,76899	10,23101	34	9,71726	9,93107	9,78618	10,21382
27	9,70482	9,93554	9,76928	10,23072	33	9,71747	9,93100	9,78647	10,21353
28	9,70504	9,93547	9,76957	10,23043	32	9,71767	9,93092	9,78675	10,21325
29	9,70525	9,93539	9,76986	10,23014	31	9,71788	9,93084	9,78704	10,21296
30	9,70547	9,93532	9,77015	10,22985	30	9,71809	9,93077	9,78732	10,21268
31	9,70568	9,93525	9,77044	10,22956	29	9,71829	9,93069	9,78760	10,21240
32	9,70590	9,93517	9,77073	10,22927	28	9,71850	9,93061	9,78789	10,21211
33	9,70611	9,93510	9,77101	10,22899	27	9,71870	9,93053	9,78817	10,21183
34	9,70633	9,93502	9,77130	10,22870	26	9,71891	9,93046	9,78845	10,21155
35	9,70654	9,93495	9,77159	10,22841	25	9,71911	9,93038	9,78874	10,21126
36	9,70675	9,93487	9,77188	10,22812	24	9,71932	9,93030	9,78902	10,21098
37	9,70697	9,93480	9,77217	10,22783	23	9,71952	9,93022	9,78930	10,21070
38	9,70718	9,93472	9,77246	10,22754	22	9,71973	9,93014	9,78959	10,21041
39	9,70739	9,93465	9,77274	10,22726	21	9,71993	9,93007	9,78987	10,21013
40	9,70761	9,93457	9,77303	10,22697	20	9,72014	9,92999	9,79015	10,20985
41	9,70782	9,93450	9,77332	10,22668	19	9,72034	9,92991	9,79043	10,20957
42	9,70803	9,93442	9,77361	10,22639	18	9,72055	9,92983	9,79072	10,20928
43	9,70824	9,93435	9,77390	10,22610	17	9,72075	9,92976	9,79100	10,20900
44	9,70846	9,93427	9,77418	10,22582	16	9,72096	9,92968	9,79128	10,20872
45	9,70867	9,93420	9,77447	10,22553	15	9,72116	9,92960	9,79156	10,20844
46	9,70888	9,93412	9,77476	10,22524	14	9,72137	9,92952	9,79185	10,20815
47	9,70909	9,93405	9,77505	10,22495	13	9,72157	9,92944	9,79213	10,20787
48	9,70931	9,93397	9,77533	10,22467	12	9,72177	9,92936	9,79241	10,20759
49	9,70952	9,93390	9,77562	10,22438	11	9,72198	9,92929	9,79269	10,20731
50	9,70973	9,93382	9,77591	10,22409	10	9,72218	9,92921	9,79297	10,20703
51	9,70994	9,93375	9,77619	10,22381	9	9,72238	9,92913	9,79326	10,20674
52	9,71015	9,93367	9,77648	10,22352	8	9,72259	9,92905	9,79354	10,20646
53	9,71036	9,93360	9,77677	10,22323	7	9,72279	9,92897	9,79382	10,20618
54	9,71058	9,93352	9,77706	10,22294	6	9,72299	9,92889	9,79410	10,20590
55	9,71079	9,93344	9,77734	10,22266	5	9,72320	9,92881	9,79438	10,20562
56	9,71100	9,93337	9,77763	10,22237	4	9,72340	9,92874	9,79466	10,20534
57	9,71121	9,93329	9,77791	10,22209	3	9,72360	9,92866	9,79495	10,20505
58	9,71142	9,93322	9,77820	10,22180	2	9,72381	9,92858	9,79523	10,20477
59	9,71163	9,93314	9,77849	10,22151	1	9,72401	9,92850	9,79551	10,20449
60	9,71184	9,93307	9,77877	10,22123	0	9,72421	9,92842	9,79579	10,20421
Co-sine	Sine	Co-tan.	Tangent.	M	Co-sine	Sine	Co-tan.	Tangent.	M
59 Degrees.					58 Degrees.				

32 Degrees.					33 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine.	Co-sine	Tang.	Co-tang.
0	9,72421	9,9284	9,79579	10,20421	60	9,73611	9,92359	9,81252	10,18748
1	9,72441	9,92834	9,79607	10,20393	59	9,73630	9,92351	9,81279	10,18721
2	9,72461	9,92826	9,79635	10,20365	58	9,73650	9,92343	9,81307	10,18693
3	9,72482	9,92818	9,79663	10,20337	57	9,73669	9,92334	9,81335	10,18665
4	9,72502	9,92810	9,79691	10,20309	56	9,73689	9,92326	9,81362	10,18637
5	9,72522	9,92803	9,79719	10,20281	55	9,73708	9,92318	9,81390	10,18610
6	9,72542	9,92795	9,79747	10,20253	54	9,73727	9,92310	9,81418	10,18582
7	9,72562	9,92787	9,79776	10,20224	53	9,73747	9,92302	9,81445	10,18555
8	9,72582	9,92779	9,79804	10,20196	52	9,73766	9,92293	9,81473	10,18527
9	9,72602	9,92771	9,79832	10,20168	51	9,73785	9,92285	9,81500	10,18500
10	9,72622	9,92763	9,79860	10,20140	50	9,73805	9,92277	9,81528	10,18472
11	9,72643	9,92755	9,79888	10,20112	49	9,73824	9,92269	9,81556	10,18444
12	9,72663	9,92747	9,79916	10,20084	48	9,73843	9,92260	9,81583	10,18417
13	9,72683	9,92739	9,79944	10,20056	47	9,73863	9,92252	9,81611	10,18389
14	9,72703	9,92731	9,79972	10,20028	46	9,73882	9,92244	9,81638	10,18362
15	9,72723	9,92723	9,80000	10,20000	45	9,73901	9,92235	9,81666	10,18334
16	9,72743	9,92715	9,80028	10,19972	44	9,73921	9,92227	9,81693	10,18307
17	9,72763	9,92707	9,80056	10,19944	43	9,73940	9,92219	9,81721	10,18279
18	9,72783	9,92699	9,80084	10,19916	42	9,73959	9,92211	9,81748	10,18252
19	9,72803	9,92691	9,80112	10,19888	41	9,73978	9,92202	9,81776	10,18224
20	9,72823	9,92683	9,80140	10,19860	40	9,73997	9,92194	9,81803	10,18197
21	9,72843	9,92675	9,80168	10,19832	39	9,74017	9,92186	9,81831	10,18169
22	9,72863	9,92667	9,80195	10,19805	38	9,74036	9,92177	9,81858	10,18142
23	9,72883	9,92659	9,80223	10,19777	37	9,74055	9,92169	9,81886	10,18114
24	9,72902	9,92651	9,80251	10,19749	36	9,74074	9,92161	9,81913	10,18087
25	9,72922	9,92643	9,80279	10,19721	35	9,74093	9,92152	9,81941	10,18059
26	9,72942	9,92635	9,80307	10,19693	34	9,74113	9,92144	9,81968	10,18032
27	9,72962	9,92627	9,80335	10,19665	33	9,74132	9,92136	9,81996	10,18004
28	9,72982	9,92619	9,80363	10,19637	32	9,74151	9,92127	9,82023	10,17977
29	9,73002	9,92611	9,80391	10,19609	31	9,74170	9,92119	9,82051	10,17949
30	9,73022	9,92603	9,80419	10,19581	30	9,74189	9,92111	9,82078	10,17922
31	9,73041	9,92595	9,80447	10,19553	29	9,74208	9,92102	9,82106	10,17894
32	9,73061	9,92587	9,80474	10,19526	28	9,74227	9,92094	9,82133	10,17867
33	9,73081	9,92579	9,80502	10,19498	27	9,74246	9,92086	9,82161	10,17839
34	9,73101	9,92571	9,80530	10,19470	26	9,74265	9,92077	9,82188	10,17812
35	9,73121	9,92563	9,80558	10,19442	25	9,74284	9,92069	9,82215	10,17785
36	9,73140	9,92555	9,80586	10,19414	24	9,74303	9,92060	9,82243	10,17757
37	9,73160	9,92546	9,80614	10,19386	23	9,74322	9,92052	9,82270	10,17730
38	9,73180	9,92538	9,80642	10,19358	22	9,74341	9,92044	9,82298	10,17702
39	9,73200	9,92530	9,80669	10,19331	21	9,74360	9,92035	9,82325	10,17675
40	9,73219	9,92522	9,80697	10,19303	20	9,74379	9,92027	9,82352	10,17648
41	9,73239	9,92514	9,80725	10,19275	19	9,74398	9,92018	9,82380	10,17620
42	9,73258	9,92506	9,80753	10,19247	18	9,74417	9,92010	9,82407	10,17593
43	9,73278	9,92498	9,80781	10,19219	17	9,74436	9,92002	9,82435	10,17565
44	9,73298	9,92490	9,80808	10,19192	16	9,74455	9,91993	9,82462	10,17538
45	9,73318	9,92482	9,80836	10,19164	15	9,74474	9,91985	9,82489	10,17511
46	9,73337	9,92473	9,80864	10,19136	14	9,74493	9,91976	9,82517	10,17483
47	9,73357	9,92465	9,80892	10,19108	13	9,74512	9,91968	9,82544	10,17456
48	9,73377	9,92457	9,80919	10,19081	12	9,74531	9,91959	9,82571	10,17429
49	9,73396	9,92449	9,80947	10,19053	11	9,74549	9,91951	9,82599	10,17401
50	9,73416	9,92441	9,80975	10,19025	10	9,74568	9,91942	9,82626	10,17374
51	9,73435	9,92433	9,81003	10,18997	9	9,74587	9,91934	9,82653	10,17347
52	9,73455	9,92425	9,81030	10,18970	8	9,74606	9,91925	9,82681	10,17319
53	9,73474	9,92416	9,81058	10,18942	7	9,74625	9,91917	9,82708	10,17292
54	9,73494	9,92408	9,81086	10,18914	6	9,74644	9,91908	9,82735	10,17265
55	9,73513	9,92400	9,81113	10,18887	5	9,74662	9,91900	9,82762	10,17238
56	9,73533	9,92392	9,81141	10,18859	4	9,74681	9,91891	9,82790	10,17210
57	9,73552	9,92384	9,81169	10,18831	3	9,74700	9,91883	9,82817	10,17183
58	9,73572	9,92376	9,81196	10,18804	2	9,74719	9,91874	9,82844	10,17156
59	9,73591	9,92367	9,81224	10,18776	1	9,74737	9,91866	9,82871	10,17129
60	9,73611	9,92359	9,81252	10,18748	0	9,74756	9,91857	9,82899	10,17101
Co-sine	Sine	Co-tan.	Tangent.	M	Co-sine	Sine	Co-tan.	Tangent.	M
57 Degrees.					56 Degrees.				

TABLE OF SINES AND TANGENTS. 145. 387

34 Degrees.					35 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9,74756	9,91857	9,82899	10,17101	60	9,75859	9,91330	9,84523	10,15477
1	9,74775	9,91849	9,82926	10,17074	59	9,75877	9,91328	9,84550	10,15450
2	9,74794	9,91840	9,82953	10,17047	58	9,75895	9,91319	9,84576	10,15424
3	9,74812	9,91832	9,82980	10,17020	57	9,75913	9,91310	9,84603	10,15397
4	9,74831	9,91823	9,83008	10,16992	56	9,75931	9,91301	9,84630	10,15370
5	9,74850	9,91815	9,83035	10,16965	55	9,75949	9,91292	9,84657	10,15343
6	9,74868	9,91806	9,83062	10,16938	54	9,75967	9,91283	9,84684	10,15316
7	9,74887	9,91798	9,83089	10,16911	53	9,75985	9,91274	9,84711	10,15289
8	9,74906	9,91789	9,83117	10,16883	52	9,76003	9,91266	9,84738	10,15262
9	9,74924	9,91781	9,83144	10,16856	51	9,76021	9,91257	9,84764	10,15236
10	9,74943	9,91772	9,83171	10,16829	50	9,76039	9,91248	9,84791	10,15209
11	9,74961	9,91763	9,83198	10,16802	49	9,76057	9,91239	9,84818	10,15182
12	9,74980	9,91755	9,83225	10,16775	48	9,76075	9,91230	9,84845	10,15155
13	9,74999	9,91746	9,83252	10,16748	47	9,76093	9,91221	9,84872	10,15128
14	9,75017	9,91738	9,83280	10,16720	46	9,76111	9,91212	9,84899	10,15101
15	9,75036	9,91729	9,83307	10,16693	45	9,76129	9,91203	9,84925	10,15075
16	9,75054	9,91720	9,83334	10,16666	44	9,76146	9,91194	9,84952	10,15048
17	9,75073	9,91712	9,83361	10,16639	43	9,76164	9,91185	9,84979	10,15021
18	9,75091	9,91703	9,83388	10,16612	42	9,76182	9,91176	9,85006	10,14994
19	9,75110	9,91695	9,83415	10,16585	41	9,76200	9,91167	9,85033	10,14967
20	9,75128	9,91686	9,83442	10,16558	40	9,76218	9,91158	9,85059	10,14941
21	9,75147	9,91677	9,83470	10,16530	39	9,76236	9,91149	9,85086	10,14914
22	9,75165	9,91669	9,83497	10,16503	38	9,76253	9,91141	9,85113	10,14887
23	9,75184	9,91660	9,83524	10,16476	37	9,76271	9,91132	9,85140	10,14860
24	9,75202	9,91651	9,83551	10,16449	36	9,76289	9,91123	9,85166	10,14834
25	9,75221	9,91643	9,83578	10,16422	35	9,76307	9,91114	9,85193	10,14807
26	9,75239	9,91634	9,83605	10,16395	34	9,76324	9,91105	9,85220	10,14780
27	9,75258	9,91625	9,83632	10,16368	33	9,76342	9,91096	9,85247	10,14753
28	9,75276	9,91617	9,83659	10,16341	32	9,76360	9,91087	9,85273	10,14727
29	9,75294	9,91608	9,83686	10,16314	31	9,76378	9,91078	9,85300	10,14700
30	9,75313	9,91599	9,83713	10,16287	30	9,76395	9,91069	9,85327	10,14673
31	9,75331	9,91591	9,83740	10,16260	29	9,76413	9,91060	9,85354	10,14646
32	9,75350	9,91582	9,83768	10,16232	28	9,76431	9,91051	9,85380	10,14620
33	9,75368	9,91573	9,83795	10,16205	27	9,76448	9,91042	9,85407	10,14593
34	9,75386	9,91565	9,83822	10,16178	26	9,76466	9,91033	9,85434	10,14566
35	9,75405	9,91556	9,83849	10,16151	25	9,76484	9,91023	9,85460	10,14540
36	9,75423	9,91547	9,83876	10,16124	24	9,76501	9,91014	9,85487	10,14513
37	9,75441	9,91538	9,83903	10,16097	23	9,76519	9,91005	9,85514	10,14486
38	9,75459	9,91530	9,83930	10,16070	22	9,76537	9,90996	9,85540	10,14460
39	9,75478	9,91521	9,83957	10,16043	21	9,76554	9,90987	9,85567	10,14433
40	9,75496	9,91512	9,83984	10,16016	20	9,76572	9,90978	9,85594	10,14406
41	9,75514	9,91504	9,84011	10,15989	19	9,76590	9,90969	9,85620	10,14380
42	9,75533	9,91495	9,84038	10,15962	18	9,76607	9,90960	9,85647	10,14353
43	9,75551	9,91486	9,84065	10,15935	17	9,76625	9,90951	9,85674	10,14326
44	9,75569	9,91477	9,84092	10,15908	16	9,76642	9,90942	9,85700	10,14300
45	9,75587	9,91469	9,84119	10,15881	15	9,76660	9,90933	9,85727	10,14273
46	9,75605	9,91460	9,84146	10,15854	14	9,76677	9,90924	9,85754	10,14246
47	9,75624	9,91451	9,84173	10,15827	13	9,76695	9,90915	9,85780	10,14220
48	9,75642	9,91442	9,84200	10,15800	12	9,76712	9,90905	9,85807	10,14193
49	9,75660	9,91433	9,84227	10,15773	11	9,76730	9,90896	9,85834	10,14166
50	9,75678	9,91425	9,84254	10,15746	10	9,76747	9,90887	9,85860	10,14140
51	9,75696	9,91416	9,84280	10,15720	9	9,76765	9,90878	9,85887	10,14113
52	9,75714	9,91407	9,84307	10,15693	8	9,76782	9,90869	9,85913	10,14087
53	9,75733	9,91398	9,84334	10,15666	7	9,76800	9,90860	9,85940	10,14060
54	9,75751	9,91389	9,84361	10,15639	6	9,76817	9,90851	9,85967	10,14033
55	9,75769	9,91381	9,84388	10,15612	5	9,76835	9,90842	9,85993	10,14007
56	9,75787	9,91372	9,84415	10,15585	4	9,76852	9,90832	9,86020	10,13980
57	9,75805	9,91363	9,84442	10,15558	3	9,76870	9,90823	9,86046	10,13954
58	9,75823	9,91354	9,84469	10,15531	2	9,76887	9,90814	9,86073	10,13927
59	9,75841	9,91345	9,84496	10,15504	1	9,76904	9,90805	9,86100	10,13900
60	9,75859	9,91336	9,84523	10,15477	0	9,76922	9,90796	9,86126	10,13874
55 Degrees.					54 Degrees.				
Co-sine	Sine	Co-tan.	Tangent.	M	Co-sine	Sine	Co-tan.	Tangent.	M

36 Degrees.					37 Degrees.						
	Sine	Co-sine.	Tang.	Co-tang.		Sine	Co-sine	Tang.	Co-tang.		
0	9.76922	9.90796	9.86126	10.13874	60	0	9.77946	9.90235	9.87711	10.12289	60
1	9.76939	9.90787	9.86153	10.13847	59	1	9.77963	9.90225	9.87738	10.12262	59
2	9.76957	9.90777	9.86179	10.13821	58	2	9.77980	9.90216	9.87764	10.12236	58
3	9.76974	9.90768	9.86206	10.13794	57	3	9.77997	9.90206	9.87790	10.12210	57
4	9.76991	9.90759	9.86232	10.13768	56	4	9.78013	9.90197	9.87817	10.12183	56
5	9.77009	9.90750	9.86259	10.13741	55	5	9.78030	9.90187	9.87843	10.12157	55
6	9.77026	9.90741	9.86285	10.13715	54	6	9.78047	9.90178	9.87869	10.12131	54
7	9.77043	9.90731	9.86312	10.13688	53	7	9.78063	9.90168	9.87895	10.12105	53
8	9.77061	9.90722	9.86338	10.13662	52	8	9.78080	9.90159	9.87922	10.12078	52
9	9.77078	9.90713	9.86365	10.13635	51	9	9.78097	9.90149	9.87948	10.12052	51
10	9.77095	9.90704	9.86392	10.13608	50	10	9.78113	9.90139	9.87974	10.12026	50
11	9.77112	9.90694	9.86418	10.13582	49	11	9.78130	9.90130	9.88000	10.12000	49
12	9.77130	9.90685	9.86445	10.13555	48	12	9.78147	9.90120	9.88027	10.11973	48
13	9.77147	9.90676	9.86471	10.13529	47	13	9.78163	9.90111	9.88053	10.11947	47
14	9.77164	9.90667	9.86498	10.13502	46	14	9.78180	9.90101	9.88079	10.11921	46
15	9.77181	9.90657	9.86524	10.13476	45	15	9.78197	9.90091	9.88105	10.11895	45
16	9.77199	9.90648	9.86551	10.13449	44	16	9.78213	9.90082	9.88131	10.11869	44
17	9.77216	9.90639	9.86577	10.13423	43	17	9.78230	9.90072	9.88158	10.11842	43
18	9.77233	9.90630	9.86603	10.13397	42	18	9.78246	9.90063	9.88184	10.11816	42
19	9.77250	9.90620	9.86630	10.13370	41	19	9.78263	9.90053	9.88210	10.11790	41
20	9.77268	9.90611	9.86656	10.13344	40	20	9.78280	9.90043	9.88236	10.11764	40
21	9.77285	9.90602	9.86683	10.13317	39	21	9.78296	9.90034	9.88262	10.11738	39
22	9.77302	9.90592	9.86709	10.13291	38	22	9.78313	9.90024	9.88289	10.11711	38
23	9.77319	9.90583	9.86736	10.13264	37	23	9.78329	9.90014	9.88315	10.11685	37
24	9.77336	9.90574	9.86762	10.13238	36	24	9.78346	9.90005	9.88341	10.11659	36
25	9.77353	9.90565	9.86789	10.13211	35	25	9.78362	9.89995	9.88367	10.11633	35
26	9.77370	9.90555	9.86815	10.13185	34	26	9.78379	9.89985	9.88393	10.11607	34
27	9.77387	9.90546	9.86842	10.13158	33	27	9.78395	9.89976	9.88420	10.11580	33
28	9.77405	9.90537	9.86868	10.13132	32	28	9.78412	9.89966	9.88446	10.11554	32
29	9.77422	9.90527	9.86894	10.13106	31	29	9.78428	9.89956	9.88472	10.11528	31
30	9.77439	9.90518	9.86921	10.13079	30	30	9.78445	9.89947	9.88498	10.11502	30
31	9.77456	9.90509	9.86947	10.13053	29	31	9.78461	9.89937	9.88524	10.11476	29
32	9.77473	9.90499	9.86974	10.13026	28	32	9.78478	9.89927	9.88550	10.11450	28
33	9.77490	9.90490	9.87000	10.13000	27	33	9.78494	9.89918	9.88577	10.11423	27
34	9.77507	9.90480	9.87027	10.12973	26	34	9.78510	9.89908	9.88603	10.11397	26
35	9.77524	9.90471	9.87053	10.12947	25	35	9.78527	9.89898	9.88629	10.11371	25
36	9.77541	9.90462	9.87079	10.12921	24	36	9.78543	9.89888	9.88655	10.11345	24
37	9.77558	9.90452	9.87106	10.12894	23	37	9.78560	9.89879	9.88681	10.11319	23
38	9.77575	9.90443	9.87132	10.12868	22	38	9.78576	9.89869	9.88707	10.11293	22
39	9.77592	9.90434	9.87158	10.12842	21	39	9.78592	9.89859	9.88733	10.11267	21
40	9.77609	9.90424	9.87185	10.12815	20	40	9.78609	9.89849	9.88759	10.11241	20
41	9.77626	9.90415	9.87211	10.12789	19	41	9.78625	9.89840	9.88786	10.11214	19
42	9.77643	9.90405	9.87238	10.12762	18	42	9.78642	9.89830	9.88812	10.11188	18
43	9.77660	9.90396	9.87264	10.12736	17	43	9.78658	9.89820	9.88838	10.11162	17
44	9.77677	9.90386	9.87290	10.12710	16	44	9.78674	9.89810	9.88864	10.11136	16
45	9.77694	9.90377	9.87317	10.12683	15	45	9.78691	9.89801	9.88890	10.11110	15
46	9.77710	9.90368	9.87343	10.12657	14	46	9.78707	9.89791	9.88916	10.11084	14
47	9.77727	9.90358	9.87369	10.12631	13	47	9.78723	9.89781	9.88942	10.11058	13
48	9.77744	9.90349	9.87396	10.12604	12	48	9.78739	9.89771	9.88968	10.11032	12
49	9.77761	9.90339	9.87422	10.12578	11	49	9.78756	9.89761	9.88994	10.11006	11
50	9.77778	9.90330	9.87448	10.12552	10	50	9.78772	9.89752	9.89020	10.10980	10
51	9.77795	9.90320	9.87475	10.12525	9	51	9.78788	9.89742	9.89046	10.10954	9
52	9.77812	9.90311	9.87501	10.12499	8	52	9.78805	9.89732	9.89073	10.10927	8
53	9.77829	9.90301	9.87527	10.12473	7	53	9.78821	9.89722	9.89099	10.10901	7
54	9.77846	9.90292	9.87554	10.12446	6	54	9.78837	9.89712	9.89125	10.10875	6
55	9.77862	9.90282	9.87580	10.12420	5	55	9.78853	9.89702	9.89151	10.10849	5
56	9.77879	9.90273	9.87606	10.12394	4	56	9.78869	9.89693	9.89177	10.10823	4
57	9.77896	9.90263	9.87633	10.12367	3	57	9.78886	9.89683	9.89203	10.10797	3
58	9.77913	9.90254	9.87659	10.12341	2	58	9.78902	9.89673	9.89229	10.10771	2
59	9.77930	9.90244	9.87685	10.12315	1	59	9.78918	9.89663	9.89255	10.10745	1
60	9.77946	9.90235	9.87711	10.12289	0	60	9.78934	9.89653	9.89281	10.10719	0
	Co-sine	Sine	Co-tan	Tangent.	M		Co-sine	Sine	Co-tan.	Tangent.	M

53 Degrees.					52 Degrees.				
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38 Degrees.					39 Degrees.				
M.	Sine	Co-line	Tang.	Co-tang.	M.	Sine	Co-line	Tang.	Co-tang.
0	9,78934	9,90539	8,9281	10,10719	00	9,79887	9,89050	9,90837	10,09163
1	9,78950	9,86439	8,9307	10,10693	59	9,79903	9,89040	9,90863	10,09137
2	9,78967	9,89633	8,9333	10,10667	58	9,79918	9,89030	9,90889	10,09111
3	9,78983	9,89624	8,9359	10,10641	57	9,79934	9,89020	9,90914	10,09086
4	9,78999	9,89614	8,9385	10,10615	56	9,79950	9,89009	9,90940	10,09060
5	9,79015	9,89604	8,9411	10,10589	55	9,79965	9,88999	9,90966	10,09034
6	9,79031	9,89594	8,9437	10,10563	54	9,79981	9,88989	9,90992	10,09008
7	9,79047	9,89584	8,9463	10,10537	53	9,79996	9,88978	9,91018	10,08982
8	9,79063	9,89574	8,9489	10,10511	52	9,80012	9,88968	9,91043	10,08957
9	9,79079	9,89564	8,9515	10,10485	51	9,80027	9,88958	9,91069	10,08931
10	9,79095	9,89554	8,9541	10,10459	50	9,80043	9,88948	9,91095	10,08905
11	9,79111	9,89544	8,9567	10,10433	49	9,80058	9,88937	9,91121	10,08879
12	9,79128	9,89534	8,9593	10,10407	48	9,80074	9,88927	9,91147	10,08853
13	9,79144	9,89524	8,9619	10,10381	47	9,80089	9,88917	9,91172	10,08828
14	9,79160	9,89514	8,9645	10,10355	46	9,80105	9,88906	9,91198	10,08802
15	9,79176	9,89504	8,9671	10,10329	45	9,80120	9,88896	9,91224	10,08776
16	9,79192	9,89495	8,9697	10,10303	44	9,80136	9,88886	9,91250	10,08750
17	9,79208	9,89485	8,9723	10,10277	43	9,80151	9,88875	9,91276	10,08724
18	9,79224	9,89475	8,9749	10,10251	42	9,80166	9,88865	9,91301	10,08699
19	9,79240	9,89465	8,9775	10,10225	41	9,80182	9,88855	9,91327	10,08673
20	9,79256	9,89455	8,9801	10,10199	40	9,80197	9,88844	9,91353	10,08647
21	9,79272	9,89445	8,9827	10,10173	39	9,80213	9,88834	9,91379	10,08621
22	9,79288	9,89435	8,9853	10,10147	38	9,80228	9,88824	9,91404	10,08596
23	9,79304	9,89425	8,9879	10,10121	37	9,80244	9,88813	9,91430	10,08570
24	9,79319	9,89415	8,9905	10,10095	36	9,80259	9,88803	9,91456	10,08544
25	9,79335	9,89405	8,9931	10,10069	35	9,80274	9,88793	9,91482	10,08518
26	9,79351	9,89395	8,9957	10,10043	34	9,80290	9,88782	9,91507	10,08493
27	9,79367	9,89385	8,9983	10,10017	33	9,80305	9,88772	9,91533	10,08467
28	9,79383	9,89375	8,9909	10,09991	32	9,80320	9,88761	9,91559	10,08441
29	9,79399	9,89364	8,9935	10,09965	31	9,80336	9,88751	9,91585	10,08415
30	9,79415	9,89354	8,9961	10,09939	30	9,80351	9,88741	9,91610	10,08390
31	9,79431	9,89344	8,9986	10,09914	29	9,80366	9,88730	9,91636	10,08364
32	9,79447	9,89334	8,9912	10,09888	28	9,80382	9,88720	9,91662	10,08338
33	9,79463	9,89324	8,9938	10,09862	27	9,80397	9,88709	9,91688	10,08312
34	9,79478	9,89314	8,9964	10,09836	26	9,80412	9,88699	9,91713	10,08287
35	9,79494	9,89304	8,9990	10,09810	25	9,80428	9,88688	9,91739	10,08261
36	9,79510	9,89294	8,9916	10,09784	24	9,80443	9,88678	9,91765	10,08235
37	9,79526	9,89284	8,9942	10,09758	23	9,80458	9,88668	9,91791	10,08209
38	9,79542	9,89274	8,9968	10,09732	22	9,80473	9,88657	9,91816	10,08184
39	9,79558	9,89264	8,9994	10,09706	21	9,80489	9,88647	9,91842	10,08158
40	9,79573	9,89254	8,9920	10,09680	20	9,80504	9,88636	9,91868	10,08132
41	9,79589	9,89244	8,9946	10,09654	19	9,80519	9,88626	9,91893	10,08107
42	9,79605	9,89233	8,9971	10,09629	18	9,80534	9,88615	9,91919	10,08081
43	9,79621	9,89223	8,9997	10,09603	17	9,80550	9,88605	9,91945	10,08055
44	9,79636	9,89213	8,9923	10,09577	16	9,80565	9,88594	9,91971	10,08029
45	9,79652	9,89203	8,9949	10,09551	15	9,80580	9,88584	9,91996	10,08004
46	9,79668	9,89193	8,9975	10,09525	14	9,80595	9,88573	9,92022	10,07978
47	9,79684	9,89183	8,9951	10,09499	13	9,80610	9,88563	9,92048	10,07952
48	9,79699	9,89173	8,9927	10,09473	12	9,80625	9,88552	9,92073	10,07927
49	9,79715	9,89162	8,9953	10,09447	11	9,80641	9,88542	9,92099	10,07901
50	9,79731	9,89152	8,9978	10,09422	10	9,80656	9,88531	9,92125	10,07875
51	9,79746	9,89142	8,9904	10,09396	9	9,80671	9,88521	9,92150	10,07850
52	9,79762	9,89132	8,9930	10,09370	8	9,80686	9,88510	9,92176	10,07824
53	9,79778	9,89122	8,9956	10,09344	7	9,80701	9,88499	9,92202	10,07798
54	9,79793	9,89112	8,9982	10,09318	6	9,80716	9,88489	9,92227	10,07773
55	9,79809	9,89101	8,9908	10,09292	5	9,80731	9,88478	9,92253	10,07747
56	9,79825	9,89091	8,9934	10,09266	4	9,80746	9,88468	9,92279	10,07722
57	9,79840	9,89081	8,9959	10,09241	3	9,80762	9,88457	9,92304	10,07696
58	9,79856	9,89071	8,9985	10,09215	2	9,80777	9,88447	9,92330	10,07670
59	9,79872	9,89060	8,9911	10,09189	1	9,80792	9,88436	9,92356	10,07644
60	9,79887	9,89050	8,9937	10,09163	0	9,80807	9,88425	9,92381	10,07619
Co-line	Sine	Co-tan.	Tangent	M.	Co-line	Sine	Co-tan.	Tangent	M.
51 Degrees.					50 Degrees.				

40 Degrees.					41 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9,80807	9,88425	9,92381	10,07619	60	9,81694	9,87778	9,93916	10,06084
1	9,80822	9,88415	9,92407	10,07593	59	9,81709	9,87767	9,93942	10,06058
2	9,80837	9,88404	9,92433	10,07567	58	9,81723	9,87756	9,93967	10,06033
3	9,80852	9,88394	9,92458	10,07542	57	9,81738	9,87745	9,93993	10,06007
4	9,80867	9,88383	9,92484	10,07516	56	9,81752	9,87734	9,94018	10,05982
5	9,80882	9,88372	9,92510	10,07490	55	9,81767	9,87723	9,94044	10,05956
6	9,80897	9,88362	9,92535	10,07465	54	9,81781	9,87712	9,94069	10,05931
7	9,80912	9,88351	9,92561	10,07439	53	9,81796	9,87701	9,94095	10,05905
8	9,80927	9,88340	9,92587	10,07413	52	9,81810	9,87690	9,94120	10,05880
9	9,80942	9,88330	9,92612	10,07388	51	9,81825	9,87679	9,94146	10,05854
10	9,80957	9,88319	9,92638	10,07362	50	9,81839	9,87668	9,94171	10,05829
11	9,80972	9,88308	9,92663	10,07337	49	9,81854	9,87657	9,94197	10,05803
12	9,80987	9,88298	9,92689	10,07311	48	9,81868	9,87646	9,94222	10,05778
13	9,81002	9,88287	9,92715	10,07285	47	9,81882	9,87635	9,94248	10,05752
14	9,81017	9,88276	9,92740	10,07260	46	9,81897	9,87624	9,94273	10,05727
15	9,81032	9,88266	9,92766	10,07234	45	9,81911	9,87613	9,94299	10,05701
16	9,81046	9,88255	9,92792	10,07208	44	9,81926	9,87601	9,94324	10,05676
17	9,81061	9,88244	9,92817	10,07183	43	9,81940	9,87590	9,94350	10,05650
18	9,81076	9,88234	9,92843	10,07157	42	9,81954	9,87579	9,94375	10,05625
19	9,81091	9,88223	9,92868	10,07132	41	9,81969	9,87568	9,94401	10,05599
20	9,81106	9,88212	9,92894	10,07106	40	9,81983	9,87557	9,94426	10,05574
21	9,81121	9,88201	9,92920	10,07080	39	9,81998	9,87546	9,94452	10,05548
22	9,81136	9,88191	9,92945	10,07055	38	9,82012	9,87535	9,94477	10,05523
23	9,81151	9,88180	9,92971	10,07029	37	9,82026	9,87524	9,94503	10,05497
24	9,81166	9,88169	9,92996	10,07004	36	9,82041	9,87513	9,94528	10,05472
25	9,81180	9,88158	9,93022	10,06978	35	9,82055	9,87501	9,94554	10,05446
26	9,81195	9,88148	9,93048	10,06952	34	9,82069	9,87490	9,94579	10,05421
27	9,81210	9,88137	9,93073	10,06927	33	9,82084	9,87479	9,94604	10,05396
28	9,81225	9,88126	9,93099	10,06901	32	9,82098	9,87468	9,94630	10,05370
29	9,81240	9,88115	9,93124	10,06876	31	9,82112	9,87457	9,94655	10,05345
30	9,81254	9,88105	9,93150	10,06850	30	9,82126	9,87446	9,94681	10,05319
31	9,81269	9,88094	9,93175	10,06825	29	9,82141	9,87434	9,94706	10,05294
32	9,81284	9,88083	9,93201	10,06799	28	9,82155	9,87423	9,94732	10,05268
33	9,81299	9,88072	9,93227	10,06773	27	9,82169	9,87412	9,94757	10,05243
34	9,81314	9,88061	9,93252	10,06748	26	9,82184	9,87401	9,94783	10,05217
35	9,81328	9,88051	9,93278	10,06722	25	9,82198	9,87390	9,94808	10,05192
36	9,81343	9,88040	9,93303	10,06697	24	9,82212	9,87378	9,94834	10,05166
37	9,81358	9,88029	9,93329	10,06671	23	9,82226	9,87367	9,94859	10,05141
38	9,81372	9,88018	9,93354	10,06646	22	9,82240	9,87356	9,94884	10,05116
39	9,81387	9,88007	9,93380	10,06620	21	9,82255	9,87345	9,94910	10,05090
40	9,81402	9,87996	9,93406	10,06594	20	9,82269	9,87334	9,94935	10,05065
41	9,81417	9,87985	9,93431	10,06569	19	9,82283	9,87322	9,94961	10,05039
42	9,81431	9,87975	9,93457	10,06543	18	9,82297	9,87311	9,94986	10,05014
43	9,81446	9,87964	9,93482	10,06518	17	9,82311	9,87300	9,95012	10,04988
44	9,81461	9,87953	9,93508	10,06492	16	9,82326	9,87288	9,95037	10,04963
45	9,81475	9,87942	9,93533	10,06467	15	9,82340	9,87277	9,95062	10,04938
46	9,81490	9,87931	9,93559	10,06441	14	9,82354	9,87266	9,95088	10,04912
47	9,81505	9,87920	9,93584	10,06416	13	9,82368	9,87255	9,95113	10,04887
48	9,81519	9,87909	9,93610	10,06390	12	9,82382	9,87243	9,95139	10,04861
49	9,81534	9,87898	9,93636	10,06364	11	9,82396	9,87232	9,95164	10,04836
50	9,81549	9,87887	9,93661	10,06339	10	9,82410	9,87221	9,95190	10,04810
51	9,81563	9,87877	9,93687	10,06313	9	9,82424	9,87209	9,95215	10,04785
52	9,81578	9,87866	9,93712	10,06288	8	9,82439	9,87198	9,95240	10,04760
53	9,81592	9,87855	9,93738	10,06262	7	9,82453	9,87187	9,95266	10,04734
54	9,81607	9,87844	9,93763	10,06237	6	9,82467	9,87175	9,95291	10,04709
55	9,81622	9,87833	9,93789	10,06211	5	9,82481	9,87164	9,95317	10,04683
56	9,81636	9,87822	9,93814	10,06186	4	9,82495	9,87153	9,95342	10,04658
57	9,81651	9,87811	9,93840	10,06160	3	9,82509	9,87141	9,95367	10,04633
58	9,81665	9,87800	9,93865	10,06135	2	9,82523	9,87130	9,95393	10,04607
59	9,81680	9,87789	9,93891	10,06109	1	9,82537	9,87119	9,95418	10,04582
60	9,81694	9,87778	9,93916	10,06084	0	9,82551	9,87107	9,95444	10,04556
Co-sine	Sine	Co-tan.	Tangent	M	Co-sine	Sine	Co-tan.	Tangent	M
49 Degrees.					48 Degrees.				

TABLE OF SINES AND TANGENTS. 145. 391

42 Degrees.					43 Degrees.				
M	Sine	Co-sine	Tang.	Co-tang.	M	Sine	Co-sine	Tang.	Co-tang.
0	9,82551	9,87107	9,95444	10,04556	60	9,83378	9,86413	9,96966	10,03034
1	9,82565	9,87096	9,95469	10,04531	59	9,83392	9,86401	9,96991	10,03009
2	9,82579	9,87085	9,95495	10,04505	58	9,83405	9,86389	9,97016	10,02984
3	9,82593	9,87073	9,95520	10,04480	57	9,83419	9,86377	9,97042	10,02958
4	9,82607	9,87062	9,95545	10,04455	56	9,83432	9,86366	9,97067	10,02933
5	9,82621	9,87050	9,95571	10,04429	55	9,83446	9,86354	9,97092	10,02908
6	9,82635	9,87039	9,95596	10,04404	54	9,83459	9,86342	9,97118	10,02882
7	9,82649	9,87028	9,95622	10,04378	53	9,83473	9,86330	9,97143	10,02857
8	9,82663	9,87016	9,95647	10,04353	52	9,83486	9,86318	9,97168	10,02832
9	9,82677	9,87005	9,95672	10,04328	51	9,83500	9,86306	9,97193	10,02807
10	9,82691	9,86993	9,95698	10,04302	50	9,83513	9,86295	9,97219	10,02781
11	9,82705	9,86982	9,95723	10,04277	49	9,83527	9,86283	9,97244	10,02756
12	9,82719	9,86970	9,95748	10,04252	48	9,83540	9,86271	9,97269	10,02731
13	9,82733	9,86959	9,95774	10,04226	47	9,83554	9,86259	9,97295	10,02705
14	9,82747	9,86947	9,95799	10,04201	46	9,83567	9,86247	9,97320	10,02680
15	9,82761	9,86936	9,95825	10,04175	45	9,83581	9,86235	9,97345	10,02655
16	9,82775	9,86924	9,95850	10,04150	44	9,83594	9,86223	9,97371	10,02629
17	9,82788	9,86913	9,95875	10,04125	43	9,83607	9,86211	9,97396	10,02604
18	9,82802	9,86902	9,95901	10,04100	42	9,83621	9,86200	9,97421	10,02579
19	9,82816	9,86890	9,95926	10,04074	41	9,83634	9,86188	9,97447	10,02553
20	9,82830	9,86879	9,95952	10,04048	40	9,83648	9,86176	9,97472	10,02528
21	9,82844	9,86867	9,95977	10,04023	39	9,83661	9,86164	9,97497	10,02503
22	9,82858	9,86855	9,96002	10,03998	38	9,83674	9,86152	9,97523	10,02477
23	9,82872	9,86844	9,96028	10,03972	37	9,83688	9,86140	9,97548	10,02452
24	9,82885	9,86832	9,96053	10,03947	36	9,83701	9,86128	9,97573	10,02427
25	9,82899	9,86821	9,96078	10,03922	35	9,83715	9,86116	9,97598	10,02402
26	9,82913	9,86809	9,96104	10,03896	34	9,83728	9,86104	9,97624	10,02376
27	9,82927	9,86798	9,96129	10,03871	33	9,83741	9,86092	9,97649	10,02351
28	9,82941	9,86786	9,96155	10,03845	32	9,83755	9,86080	9,97674	10,02326
29	9,82955	9,86775	9,96180	10,03820	31	9,83768	9,86068	9,97700	10,02300
30	9,82968	9,86763	9,96205	10,03795	30	9,83781	9,86056	9,97725	10,02275
31	9,82982	9,86752	9,96231	10,03769	29	9,83795	9,86044	9,97750	10,02250
32	9,82996	9,86740	9,96256	10,03744	28	9,83808	9,86032	9,97776	10,02224
33	9,83010	9,86728	9,96281	10,03719	27	9,83821	9,86020	9,97801	10,02199
34	9,83023	9,86717	9,96307	10,03693	26	9,83834	9,86008	9,97826	10,02174
35	9,83037	9,86705	9,96332	10,03668	25	9,83848	9,85996	9,97851	10,02149
36	9,83051	9,86694	9,96357	10,03643	24	9,83861	9,85984	9,97877	10,02123
37	9,83065	9,86682	9,96383	10,03617	23	9,83874	9,85972	9,97902	10,02098
38	9,83078	9,86670	9,96408	10,03592	22	9,83887	9,85960	9,97927	10,02073
39	9,83092	9,86659	9,96433	10,03567	21	9,83901	9,85948	9,97953	10,02047
40	9,83106	9,86647	9,96459	10,03541	20	9,83914	9,85936	9,97978	10,02022
41	9,83119	9,86635	9,96484	10,03516	19	9,83927	9,85924	9,98003	10,01997
42	9,83133	9,86624	9,96510	10,03490	18	9,83940	9,85912	9,98029	10,01971
43	9,83147	9,86612	9,96535	10,03465	17	9,83954	9,85900	9,98054	10,01946
44	9,83161	9,86600	9,96560	10,03440	16	9,83967	9,85888	9,98079	10,01921
45	9,83174	9,86589	9,96586	10,03414	15	9,83980	9,85876	9,98104	10,01896
46	9,83188	9,86577	9,96611	10,03389	14	9,83993	9,85864	9,98130	10,01870
47	9,83202	9,86565	9,96636	10,03364	13	9,84006	9,85851	9,98155	10,01845
48	9,83215	9,86554	9,96662	10,03338	12	9,84020	9,85839	9,98180	10,01820
49	9,83229	9,86542	9,96687	10,03313	11	9,84033	9,85827	9,98206	10,01794
50	9,83242	9,86530	9,96712	10,03288	10	9,84046	9,85815	9,98231	10,01769
51	9,83256	9,86518	9,96738	10,03262	9	9,84059	9,85803	9,98256	10,01744
52	9,83270	9,86507	9,96763	10,03237	8	9,84072	9,85791	9,98281	10,01719
53	9,83283	9,86495	9,96788	10,03212	7	9,84085	9,85779	9,98307	10,01693
54	9,83297	9,86483	9,96814	10,03186	6	9,84098	9,85766	9,98332	10,01668
55	9,83310	9,86472	9,96839	10,03161	5	9,84112	9,85754	9,98357	10,01643
56	9,83324	9,86460	9,96864	10,03136	4	9,84125	9,85742	9,98383	10,01617
57	9,83338	9,86448	9,96890	10,03110	3	9,84138	9,85730	9,98408	10,01592
58	9,83351	9,86436	9,96915	10,03085	2	9,84151	9,85718	9,98433	10,01567
59	9,83365	9,86425	9,96940	10,03060	1	9,84164	9,85706	9,98458	10,01542
60	9,83378	9,86413	9,96966	10,03034	0	9,84177	9,85693	9,98484	10,01516
47 Degrees.					46 Degrees.				
Co-sine	Sine	Co-tan.	Tangent.	M	Co-sine	Sine	Co-tan.	Tangent.	M

44 Degrees.				
M	Sine	Co-sine	Tangent.	Co-tang.
0	9,84177	9,85693	9,98484	10,01516
1	9,84190	9,85681	9,98509	10,01491
2	9,84203	9,85669	9,98534	10,01466
3	9,84216	9,85657	9,98560	10,01440
4	9,84229	9,85645	9,98585	10,01415
5	9,84242	9,85632	9,98610	10,01390
6	9,84255	9,85620	9,98635	10,01365
7	9,84269	9,85608	9,98661	10,01339
8	9,84282	9,85596	9,98686	10,01314
9	9,84295	9,85583	9,98711	10,01289
10	9,84308	9,85571	9,98737	10,01263
11	9,84321	9,85559	9,98762	10,01238
12	9,84334	9,85546	9,98787	10,01213
13	9,84347	9,85534	9,98812	10,01188
14	9,84360	9,85522	9,98838	10,01162
15	9,84372	9,85510	9,98863	10,01137
16	9,84385	9,85497	9,98888	10,01112
17	9,84398	9,85485	9,98913	10,01087
18	9,84411	9,85473	9,98939	10,01061
19	9,84424	9,85460	9,98964	10,01036
20	9,84437	9,85448	9,98989	10,01011
21	9,84450	9,85436	9,99015	10,00985
22	9,84463	9,85423	9,99040	10,00960
23	9,84476	9,85411	9,99065	10,00935
24	9,84489	9,85399	9,99090	10,00910
25	9,84502	9,85386	9,99116	10,00884
26	9,84515	9,85374	9,99141	10,00859
27	9,84528	9,85361	9,99166	10,00834
28	9,84540	9,85349	9,99191	10,00809
29	9,84553	9,85337	9,99217	10,00783
30	9,84566	9,85324	9,99242	10,00758
31	9,84579	9,85312	9,99267	10,00733
32	9,84592	9,85299	9,99293	10,00707
33	9,84605	9,85287	9,99318	10,00682
34	9,84618	9,85274	9,99343	10,00657
35	9,84630	9,85262	9,99368	10,00632
36	9,84643	9,85250	9,99394	10,00606
37	9,84656	9,85237	9,99419	10,00581
38	9,84669	9,85225	9,99444	10,00556
39	9,84682	9,85212	9,99469	10,00531
40	9,84694	9,85200	9,99495	10,00505
41	9,84707	9,85187	9,99520	10,00480
42	9,84720	9,85175	9,99545	10,00455
43	9,84733	9,85162	9,99570	10,00430
44	9,84745	9,85150	9,99596	10,00404
45	9,84758	9,85137	9,99621	10,00379
46	9,84771	9,85125	9,99646	10,00354
47	9,84784	9,85112	9,99672	10,00328
48	9,84796	9,85100	9,99697	10,00303
49	9,84809	9,85087	9,99722	10,00278
50	9,84822	9,85074	9,99747	10,00253
51	9,84834	9,85062	9,99773	10,00227
52	9,84847	9,85049	9,99798	10,00202
53	9,84860	9,85037	9,99823	10,00177
54	9,84873	9,85024	9,99848	10,00152
55	9,84885	9,85012	9,99874	10,00126
56	9,84898	9,84999	9,99899	10,00101
57	9,84911	9,84986	9,99924	10,00076
58	9,84923	9,84974	9,99949	10,00051
59	9,84936	9,84961	9,99975	10,00025
60	9,84949	9,84949	10,00000	10,00000
Co-sine	Sine	Co-tang.	Tangent.	M
45 Degrees.				

END OF BOOK IX.



A

TRE·ATISE

OF

MARINE FORTIFICATION.

I. **BY** MARINE FORTIFICATION is meant the art of raising works for the defence of a harbour against the attacks of any kind of shipping.

As the works proper for this purpose depend in a great measure on the principles employed in the fortification of towns, it will be necessary to give some general notions of the usual methods of fortifying, previous to the measures that seem most effectual to the securing of harbours.

It is not intended in this tract to give a complete system of fortification; and consequently the reader will not be perplexed with the different systems, as they are called, of this and that *Engineer*; many of them being the productions of dabblers in the art, who, having diverted themselves with whimsical scratchings on paper, published their conceits for a like amusement to others; and gravely compared their *pretty drawings* with the approved works of experienced Engineers. It is high time that most of their names and notions were forgot, and that those who hereafter may write on this subject, should confine themselves to the description of such works only as are most in use, and which by experience have been found to be most conducive to the defence of the place, and the retardation of the approaches of the enemy. And this is what is briefly attempted in the following pages.

2 MARINE FORTIFICATION.

PART I.

Of Land Fortifications.

2. FORTIFICATION is the art of making certain works about a place, by which the persons within may be able to defend themselves against the attacks of a much greater number from without, more effectually and longer than if the place were not furnished with such works.

3. Defensive works usually consist of moats and banks, covering the place which they defend.

4. A place is said to be covered, either when the enemy is prevented from coming to that place by a body of troops or other hindrance; or, when a sufficiently strong bank, raised before that place, prevents those without from seeing them within.

5. Defensive works are of various kinds; the most simple are usually called lines.

SECTION I.

Of Lines or Intrenchments.

6. A LINE, or an INTRENCHMENT, consists of a bank of earth, and a ditch, and it is of two sorts.

First, Such as the trenches carried on in a siege, where the bank is between the ditch and the enemy or town; and here the earth is thrown up against the town, because the workmen are thereby better covered in carrying on the works.

Secondly, Such as serve to inclose a town or camp, secure a pass, cover the entrance into a country, or other place, &c.; in these the ditch is between the bank and the enemy.

The first fort is usually called trenches or approaches: and the second is generally called lines; which are the sort that will be here more particularly treated on.

7. Lines are generally made to shut up an avenue or entrance to some place; the sides of that entrance being covered by rivers, woods, mountains, morasses, or other obstructions not easy to be passed by an army; though there have been cases where lines were constructed in plain countries; but then they were carried quite round the place they were to defend, as the lines surrounding a camp, called lines of circumvallation. Lines are likewise thrown up to stop the progress of an army, as those made by Marshal Villars and others. However, in what follows it will be supposed that the line is to cover a pass that can be attacked only in front.

8. The making of lines greatly depends on the nature of the place, and the time that can be taken to construct them; those made at leisure being very different from those made in haste.

The

The works usually thrown up in haste are called *temporary*, serving chiefly on a present emergency: those made at leisure are generally intended to last many years, and are kept in repair, under a probability of their being frequently attacked. But whether the work be temporary or lasting, it is necessary that it be adapted to the materials at hand, or that can be procured with the least expence and trouble.

A road or pass may be advantageously held by few men against a much greater number, many ways; as by turning a water-course, planting stakes, felling trees, digging ditches, making a fence of stones, &c. But the way now most usually practised is to make a line after the method contained in the following precepts.

9. *To throw up a line across a pass.*

1st. Having chosen the place most convenient for the line, let a rope, or haybands, or twisted straw or grass, be run quite across the way along the intended place of the line, pegged to the ground at every 4 or 5 yards; and at the distance of about 10 or 12 feet before the line, toward the enemy, let such another line, or a row of stakes, be carried in a position parallel to the first rope.

2d. Range the labourers or troops within those limits, either single, in pairs, or treble, &c. according to their number, or the time in which the work is to be done, each being furnished with proper digging tools.

3d. Let the earth, as they dig it up in this breadth, be thrown on the other side of the first rope, until a bank of about 5 or 6 feet thick and 6 or 7 feet high be raised; observing that the sides of the ditch be sloped in the same manner that the earth naturally rolls down the bank; and continue the digging till the ditch is about 5 or 6 feet deep, the breadth of the bottom being about $\frac{1}{3}$ of the breadth staked out at top. And while the ditch is digging, if the earth as it is thrown up be trodden down, the bank will be more compact; or a few hand-rammers (such as the pavours use) kept constantly going, will render the work more firm and durable.

4th. Let the inner side of the bank be pared with the spade into such a slope, as a man standing upright may easily touch, with his arm extended straight before him; and at the foot of this bank, let a *foot-bank* or step be raised, of such a height, that a man standing on it may easily fire his musket over the bank; that is, let the top of the foot-bank be about four feet and half lower than the top of the bank or *breast-work*.

5th. If there is time and opportunity, let the workmen throw up the loose and scattered earth upon the bank, on both sides, and flap or beat it with the flats of their shovels to make it the more neat and compact. Also make a gentle slope to the top of the *foot-bank*, that the troops may ascend it more easily; and let the *crown* or *top* of the *breast-work* be
* A 2
sloped

4 MARINE FORTIFICATION.

sloped so that a musket laid flat on it may strike the ground with its shot about 5 or 6 feet beyond the ditch.

When the soil is clay, sand, turf, or mould, the workmen will need only spades and shovels; when gravelly or stony, one man should break the ground with a pick-axe or mattock, while another throws it upon the bank, where a third should spread it level and tread it down.

10. A work of this kind being completed, the troops behind the line may wait the coming of an enemy with less concern: For 1st, the bank or breast-work secures them from the enemy's fire. 2d. And when they stand on the foot-bank, they are more than $\frac{2}{3}$ covered, while the enemy are wholly exposed; and consequently the troops within may make three of their shots tell for one of the enemy's. 3d. They can, by going off the foot-bank, be quite covered while they load again. And on the whole, they are in no great danger of being forced from the lines while they have courage enough to keep possession of them, except the enemy are greatly superior in numbers and cannon.

The magnitude of lines are generally proportioned to the little time that can be spared to throw them up, and to the strength of the enemy who are to attack them. The following forts are what have been practised on several emergencies, and the rate at which men ordinarily work on such occasions.

11. *A TABLE of the dimensions of Lines.*

Breast-work			Ditch			Expence.	
Thickness at top	Height within	Height without	Upper breadth	Lower breadth	Depth	Solid content	Days works
4 feet	$7\frac{1}{2}$ feet	6 feet	8 feet	$2\frac{2}{3}$ feet	5 feet	$4\frac{2}{3}$ ft.	1
5	$7\frac{1}{2}$	6	10	$3\frac{1}{4}$	$5\frac{1}{2}$	$6\frac{1}{2}$	$1\frac{1}{2}$
6	$7\frac{1}{2}$	6	12	4	6	8	2
7	$7\frac{1}{2}$	6	14	$4\frac{2}{3}$	$6\frac{1}{2}$	10	$2\frac{1}{2}$
8	$7\frac{1}{2}$	6	16	$5\frac{1}{3}$	7	12	3
9	$7\frac{1}{2}$	6	18	6	$7\frac{1}{2}$	15	$3\frac{1}{2}$

The days work here is one yard in length.

In the first, 100 men will complete 100 yards in length of this kind of lines in one day; 200 men in half a day; 400 men in a quarter of a day, and so on.

12. When lines are thrown up at leisure, then the ditch is usually 18 feet broad at top, 7 or 8 feet deep, and the sides of the ditch are so sloped, as to leave only 6 feet breadth at bottom; the breast-work, or parapet, is about 7 feet thick on the top or crown, and 7 or 8 feet high.

In Plate XV. fig. 1. shews the heights, depths, and breadths of the several parts of a line, well designed and finished.

Where

Where IL represents the ground line, or surface of the place.

AB, the breadth of the ditch at the top.

CD, the breadth of the ditch at bottom.

FAC, is the slope or scarp of the parapet and ditch.

DBK, is the counterescarp.

EF, the top or crown of the parapet or breast-work.

EG, the inner slope of the parapet.

HG, the top of the foot-bank.

HI, the slope of the foot-bank.

BKL, a small sloping bank called the glacis.

13. This figure is called a section or profile, and may be thus drawn.

1st. In the ground-line, lay off, from any scale of equal parts, the distances $Ia=6$ feet, $ab=4$ ft. $bc=1\frac{1}{2}$ ft. $cd=7$ ft. $dA=4\frac{1}{2}$ ft.

$Af=6$ feet, $fg=6$ ft. $gB=6$ ft. $BL=5$ ft.

2d. Through a, b, c, d, e, f, g, B , draw lines perpendicular to IL.

3d. Make $aH=2\frac{1}{2}$ ft. $=bG$, $cE=7$ ft. $dF=6$ ft. $fC=8$ ft. $=gD$.

4th. Draw $IA, HG, GE, EF, FAC, CD, DB$, which continue till it meets the line FL, and the profile is constructed.

14. When lines are made to cover a camp, or a large tract of land where a considerable body of troops are posted, the work is not made in one straight, or uniformly bending line; but at certain distances, the lines projecting in salient angles toward the enemy. These projections, salient angles, are called REDENTS, or FLANKERS; because the fire from them takes the enemy in flank or sideways as they march to attack the lines.

The distance between the salient angles of the flankers is usually between the limits of 200 and 260 yards; the ordinary flight of a musket-ball, point blank, being generally within those limits; although muskets a very little elevated, will do effectual service at the distance of 360 yards.

15. A flanker consists of two lines, called faces, meeting in a point, and forming an angle called the *salient angle*, or *flanked angle*.

The part of the line between two adjacent flankers is called the *curtin*.

The *gorge* of a flanker is the distance between its faces taken at their intersection with the curtains.

16. In Plate XV. fig. 2. shews the forms of the usual lines; where the figures, CAB, cab , are redents or flankers.

AC, AB, ac, ab , the faces.

CB, cb , the gorges.

AD, ad , the capitals.

Bb , the curtin.

The angle CAB, cab , the salient, or flanked, angle.

The distance of the salient angles is about 240 yards on a mean.

The length of the capital is usually between 40 and 50 yards.

The length of the gorges is also about 60 or 70 yards.

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17. To make a Plan of lines with redents. Plate XV. Fig. 3.

1st. Let the line EEEE, &c. be so drawn, if possible, that wherever there is a bend or angle, it may either be at once, or twice, or thrice, &c. the length of about 240 yards from one another, whereby a redent will always be where there is an angle.

2d. In this line lay off distances of 240 yards each, as from E to E, E to E, &c. reckoning from the bends toward each end, whether it happens that the line will, or will not be exactly measured by a repetition of the 240 yards.

3d. At each point E draw the *capital* EF in a perpendicular position to the direction of the line in that point, and make the *capitals* about 40 or 50 yards long.

4th. On each side of E take the *half gorge*, EG, EG, each of about 30 or 35 yards, and draw the *faces* FG, FG; and the out-line, or *master-line* of the curtains and redents are formed.

5th. Parallel to each *curtin* and *face* draw lines, within, at the distances from the *master-line*, of 7 feet, 8 feet, 12 feet, and 18 feet.

Then the breadth of 7 feet represents the plan of the *parapet*.

of 1 foot

its inner slope.

of 4 feet

the top of the *foot-bank*.

of 6 feet

the *foot-bank* slope.

6th. On the outside of the *master-line*, draw lines at the distances of $10\frac{1}{2}$, $16\frac{1}{2}$, and $22\frac{1}{2}$ feet, parallel to each *curtin* and *face*; and these will represent the plans of the *scarp*, *ditch*, and *counterscarp*; observing that the salient angles of the *counterscarp* are rounded before the angles of the redents.

When the plans are drawn from a large scale, all the lines before mentioned are drawn; but when the plan is drawn from a small scale, as of 20 yards or more to an inch, then the plan is usually represented by four parallel lines; one without the *master-line*, representing the *counterscarp* or out-line of the *ditch*; and two within, representing the breadths of the *parapet* and *foot-bank*.

Sometimes a short line is hastily formed by a CHEVAUX DE FRISE; which is a beam of 6 or 8 inches square, and 10 or 12 feet long; the sides being bored through with holes about an inch and half diameter, and 6 inches distant from one another; through each hole goes a staff of about 5 or 6 feet long, armed at both ends with an iron spike, so that which way soever it is laid along, one row of pikes is presented against the enemy. A line is formed of these pieces by chaining together a sufficient number of them end to end.

In countries where there is plenty of wood, a line may be formed by laying, in a position pointing to the enemy, the stems of trees and their larger branches, piled one on another to a sufficient height, and the interstices filled with earth. Such a work, called an ABBATIS, affords an excellent defence; as was experienced at Ticonderoga.

SECTION II.

18.

Of Batteries.

When lines are to be vigorously defended against a potent enemy, it is proper to raise *batteries*; that is, works from which cannon may play on the troops as they advance to the attack: these batteries are either *open* or *covered*.

19. An OPEN BATTERY is only a number of cannon, generally *field-pieces* (that is, such as carry a ball not exceeding 9 pounds weight) ranged in a line or row abreast of one another, on some natural small elevation of the ground; or an artificial bank of about a yard or two high. These cannon are ranged at about 15 or 16 feet distant from one another, having their shot and loading utensils lying by their side; and the powder lodged in a hole at some distance behind the battery. A less distance than about 15 feet from gun to gun might occasion danger, considering the hot service for which such batteries are erected.

20. A COVERED BATTERY is when the cannon and gunners are covered by a bank made of brushwood, faggots, and earth; of about 18 or 20 feet thick, and 7 or 8 feet high. The cannon used in such batteries are generally from 9 to 18 pounders; and sometimes 24 pounders are used in them.

21. The faggots, or, as they are most usually called, the FASCINES, are made of the middling-sized loppings of trees, under an inch diameter, and are of three different lengths, 6, 9, and 12 feet, according to the work they are intended for: they are usually bound or tied round with wyths; the shortest in two places, the next in three, and the longest have four bands. These fascines are commonly 8 or 9 inches thick throughout, the ends being cut so as not to be tapering.

The fascines are fixed to the ground, and to one another, by stakes called PICKETS, like birch broom-sticks, but stronger; they are about an inch, or inch and half thick, and from 3 to 6 feet long; the 6 feet ones are in number about $\frac{2}{3}$ of the 3 feet pickets, but much stronger.

All *field batteries* consist of four chief parts, namely, the *ditch*, the *parapet*, the *platform*, and the *magazine*.

22.

Of the Ditch.

The ditch is usually dug in the front and sides, and sometimes quite round; and serves not only to furnish the earth necessary for the parapet, but it also prevents the enemy from entering the battery so readily as he might otherwise do. The ditch in front is commonly 18 or 20 feet broad, and the depth about 7 or 8 feet; the sides sloping toward the bottom, which is about 6 feet wide; but the ditches on the sides are about 10 feet wide, and 6 feet deep. These are the dimensions usually given; but the general practice seems to be, only to get earth sufficient for the work, and not mind the regularity of the ditch: for as these works in attacks are usually done by night, the keeping strictly to the assigned dimensions is hardly practicable.

23.

Of the Parapet.

The parapet is generally raised about 3 or 4 feet distant from the brink of the ditch, the space left between, called the BERM or FORELAND, serving to lodge the rubbish beat down by the enemy's shot, that it may not fall into the ditch.

The thickness of the parapet should be about 18 or 20 feet, in order to be cannon proof, and about 7 or 8 feet high, when the enemy has no command above the battery. But if they have a command over this height, the parapet should be raised high enough to cover the men while they load the guns.

The length of the parapet depends on the number of guns to be employed in the battery.

24. Thus for one gun, allow 8 yards in length.

And 6 yards more for every other gun.

So 2 guns has 14 yards; 3 guns 20 yards; 4 guns 26 yards, &c.

25. There should be great care taken that the battery be not *enfiladed* or *raked* by the enemy's cannon: neglects of this kind are often fatal to the officers and gunners, as was well known at the siege of Carthage, anno 1741. But this is easily prevented by raising at one, or both ends of the parapet, a bank across the battery called an *epaulement*, of the same thickness and height with the parapet, and about 15 or 18 feet long.

26. The parapet consists of two parts, namely, the *wall* and the *merlons*.

The WALL is that part of the parapet which is contained in one piece from end to end, and is about $2\frac{1}{2}$ or three feet high.

The MERLONS are detached pieces of the parapet, leaving openings called EMBRASURES, through which the cannon deliver their shot.

The embrasures should be cut as much as is possible perpendicular to the parapet; therefore the battery should be parallel, or nearly so, to the object to be battered: for the direct shots have most force; and oblique embrasures weaken the merlons, or parts of the parapet standing between the embrasures.

27. The embrasures are usually about 2 or $2\frac{1}{2}$ feet wide on the inside, and about 9 or 10 feet on the outside; so that the cannon may be traversed from the right to the left, and command a pretty large extent in front. The distance from the middle of one embrasure to the middle of the next should be about 18 feet, in order to leave sufficient room for the working of the guns, and the stowage of the shot and other necessaries.

28.

Of the Platform.

The PLATFORM is a floor made to facilitate the rolling of the carriage wheels, and to prevent them from sinking into the ground by the weight of the cannon, especially in wet weather.

Platforms are generally laid sloping toward the parapet 9 or 10 inches; this carries off the rain, prevents the gun from recoiling so much when fired as it would do if laid level; and when loaded, it is more easily brought to the embrasure.

29. In temporary batteries the platforms are made of planks laid across some ground timbers or sleepers; there is usually a platform made to each gun; it is about 18 feet long, 8 feet broad next the parapet, and about 14 feet broad at the tail, the intermediate spaces between the platforms serving for the shot and other necessities.

30. When a platform is to be laid on marshy ground; first lay a floor or two of fascines; cover these with *burdles* of 12 or 15 feet long, and 6 or 7 broad; on these lay a floor of 3 or 4 inches of earth, in which the sleepers are to be laid, and over them the planks.

31. When a battery is built of stone or brick, the platform is generally a flat-stone pavement ranging the whole length of the battery. This, on account of its resisting the injuries of the weather for a long time, is to be preferred to planks; but in case of a bombardment such a platform is to be avoided, because the shells will not only break the pavement, but also, by driving about the broken stones, do the troops much mischief.

32. *Of the Magazine.*

The magazine to a field battery is usually made about 50 or 60 yards behind the platform. It is a cavity dug in the ground about 4 feet deep, and the earth thrown between the pit and the platform; the sides of the pit are sometimes planked round to keep it dry, and prevent the earth from crumbling in; and the powder barrels placed there, are covered with hurdles and earth, or tanned hides, to preserve the powder from wet and fire.

The communication to the magazine is by a sloping trench beginning to descend about 5 or 6 yards behind the platform; and the earth thrown on that side, where it will most conveniently cover the persons, who remove the barrels of powder from the great magazine to the battery, or small magazine.

33. When there are many cannon in battery, and the service is quick, it is customary to have to every two pieces a small magazine to hold 20 or 30 barrels of powder. This is placed about 15 or 20 yards behind the platform, and against the merlon between the cannon; and as these barrels are used, they are replaced by others from the great magazine.

At each magazine a centinel is placed to prevent accidents.

And to prevent persons coming into the battery and magazines who have no business there, a trench is sometimes dug behind the magazine; and carried into the trenches which communicate between the magazine and battery.

34. *To construct a Fascine battery.*

For one gun provide 600 fascines of 9 ft. 100 of 6 ft. 120 of 3 ft. And, for every other piece 400 100; 100; each fascine being about 9 inches thick; and let there be three or four pickets for every fascine, for many will break in driving.

Trace the limits of the parapet in two parallel lines about 18 feet distant, allowing 8 yards in length for one gun, and 6 yards for every other gun; and along these lines cut a trench about half spade deep.

Lay

Lay a row of 9 feet fascines along one trench, observing that their ends be well jammed one into the other, and let each be pegged down with two pickets, driven into the ground till the head is sunk into the fascine.

Close to this row lay another, the two end ones being of 6 feet, and the rest 9 feet, which will prevent the joinings in this row from falling against the joinings in the first row: let these also be staked down as before. Close to the second row lay a third, all of 9 feet. Close to the third lay a fourth, the two end ones being 6 feet, and the rest 9 feet. In this manner lay the rows of fascines within the limits staked out, which will be covered with 24 rows; then over this floor of fascines throw earth to fill up the hollows, and let the whole be trod or rammed down.

On the first floor lay a second, observing, that as in the first floor every second row ended with 6 feet fascines, so in the second floor every odd row should end with 6 feet ones, and the joinings of no two fascines in this floor will fall over the joining of the fascines below them. Let the outside rows in the second floor be so placed over those in the lower, that there be a little sloping preserved, the work narrowing upward. The pickets which stake down this floor are to be driven up to the head, and the channels or hollows in the floor are to be filled up with earth. In this manner lay four floors, which will raise the work to about $2\frac{1}{2}$ or 3 feet, and that part of the breast-work called the wall will be completed.

35.

To stake out the Merlons.

Measure from each end of the wall 12 feet, there place a stake; and plant other stakes at every intermediate 18 feet; this being done on the inside of the wall, let other stakes be planted on the outside, either directly opposite the former, or in the line toward the place where the gun is more particularly intended to deliver its shot. Plant other stakes on the inside, one a foot distant on each side the former, and this will leave spaces of two feet each for the inner opening of the embrasures: then on the outside, plant other stakes at 5 or 6 feet distance from the former ones, one on each side, and spaces of 10 or 12 feet will be marked out for the outside openings of the embrasures.

In the direction of the pickets, which limit the inner and outer openings of the embrasures, let single rows of fascines be staked down across the wall, and these will be the sides of the embrasures. Fill the intermediate spaces or merlons with rows of fascines laid lengthwise to the wall, and this will be the first floor of the merlon, which is to be picketted down, and the hollows filled with earth as before directed. Let other floors be raised in like manner, until the merlons are carried up about 5 or 6 feet, or more if necessary; and on the top of each let a bed or floor of earth be laid about 8 or 12 inches thick.

Across the top of the inner opening of the embrasure, lay a bundle of 10 or 12 fascines bound together, or as many stuff into a kind of basket open at both ends, and the bundle well staked to the merlons.

Provide a *blind* made of planks 3 or 4 inches thick to fit the inner opening of the embrasure, which is to be put up while the gunners are loading the piece, to preserve them from the fire of the musketry.

The

The cheeks or sides of the embrasures are to slope, so as to have the top wider than the bottom; which not only leaves a greater opening for the blast of the gun, but these slopes, in works of this kind, give a greater degree of strength to support themselves against the bearing of the upper parts.

36. *To construct the Platforms.*

Against each embrasure lay on the ground five pieces of timber, called sleepers, about 18 feet long, and 6 or 8 inches square; let the ends next the embrasure be placed at such a distance from one another, that the distance from out to out be about 6 feet, the other ends spreading about 12 or 14 feet from out to out; drive two stakes about 3 inches square into the ground on both sides of each end of every sleeper, by which they will be kept steady in their places, and let the earth be well rammed and beat up close to them: but observe to let the tails of the sleepers be raised about 6 or 8 inches higher than the ends next the wall, to prevent the cannon from recoiling too much when fired.

Cover the sleepers with planks about two inches thick laid cross-wise; that next the embrasures being about 8 feet long, the rest gradually increasing, so that the plank at the tail be about 14 feet long; and let the planks be nailed to the sleepers.

On this floor fix a piece of timber about 6 or 8 inches square next the embrasure, to serve as a spur for the carriage wheels to knock against (which is therefore usually called the *knocker*) when the gun is run up to the wall; observing that the spur be laid parallel to the object to be battered.

The whole platform should be of oak, if it can be had.

37. If there is any danger of the battery's being raked by the enemy's cannon, let an *epaulement* or *screen* be raised at one or both ends of the parapet, joining to it, and constructed by floors of fascines, laid as before shewn: then all the straggling twigs of the fascines being cut off, the battery is constructed.

A battery thus made will do in case of haste, and where earth enough is not easily had: but as it is subject to be fired when the wood is dry, it is not so much in use as another fort called a coffer battery; especially where wood is scarce and earth plenty.

A COFFER BATTERY is that, where the sides only of the wall and merlons are formed of fascines, and all the cavities or included spaces filled with earth.

38. *To make a Coffer battery.*

The place of the battery being determined, mark out with a line the limits of the parapet 18 or 20 feet thick; and 3 or 4 feet before the parapet mark out with lines or stakes the limits of the ditch, 10 or 12 feet broad, or more if earth is wanted; allowing 8 yards in length for one gun, and 6 yards more for every other gun.

On the outlines of the parapet, cut a trench 5 or 6 inches wide and deep, and there lay a row of fascines, the ends being jammed one into the other; let these be staked down. Lay on them another row, so that the
joinings

joinings of these be not directly over the joinings of the lower one, and the knots of all the bands turned inwards; stake these down; and on them lay in like manner a third and fourth row, &c. until the height be about 3 feet. The same kind of work being done at the ends, and for the epaulement if wanted, the coffer for the wall will be made.

Then let the men be disposed along the place intended for the ditch, and with the proper tools break the ground and throw it into the coffer; where, as the earth is thrown in, another set of men are to spread it, and stamp it down with rammers; and this work is to be continued until the coffer is filled.

39. When the wall is finished, let the embrasures be staked out as before (35), and a coffer formed in like manner for each merlon, which is also to be filled with earth and rammed down.

The other articles in the preceding battery are to be followed in this, the only difference being in the making of the parapet.

When a proper place for a temporary battery is destitute both of dry earth and wood, then materials must be carried to the place; these usually are *gabions* and *earth-sacks*.

The *EARTH-SACKS* are only bags to carry earth in.

A *GABION* is a large basket without a bottom: they are of various sizes, as from 3 feet high and $2\frac{1}{2}$ or 3 feet diameter, to 6 or 8 feet high and 6 or 7 feet diameter.

40.

To make a Gabion battery.

Along the line marked out for the battery, let the gabions be planted in the places where the merlons are to be: the gabions used are of 5, 6, and 7 feet diameter, and 8 feet high. Each merlon must have 7; that is, 3 within of six feet diameter, next two of 7 feet diameter, and on the outside two of 5 feet diameter; observing to leave proper openings for the embrasures, about 2 feet on the inside, and 9 or 10 on the outside.

Or thus: Let the merlons be made of gabions 5 feet diameter; then put four within, three in the middle, and two on the outside; this construction being rather stronger than the former.

The ends and epaulements are also formed by three rows of gabions.

The floors or bottoms of the embrasures are to be filled with gabions about three feet high, and of a proper diameter to fill up the spaces between the merlons.

The gabions being placed are to be filled with earth brought from the nearest places in the earth-sacks; or else they may be filled with dung mingled with sand; and in cases of necessity, they may be filled with large faggots, or billet wood, observing that the voids between the gabions are filled also.

Batteries of this construction are usually made on marshy or rocky ground.

41. The *Sieur Remy*, in his *Memoirs of Artillery*, has given a table for the ready finding of all the requisites for the construction of temporary batteries, and for their daily service, the pieces being 24 pounders; and although these batteries are calculated only for sieges, and are of the coffer-kind, yet from this table may be derived such notions, as will greatly help young artists on other occasions.

It

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It is also proper to mention the number of fascines and pickets, that is usually expected every day from the labour of each man employed in that service.

Of fascines 5 or 6 feet long, and 5 or 6 inches thick, bound with two wyth bands each, one man will make 16 or 18 in a day, with two pickets to each.

Of fascines 8 or 9 feet long by 8 or 9 inches thick, and two pickets to each, one man usually makes 10 or 12 in a day.

Of fascines 12 feet long by 9 inches thick, with three pickets to each, 8 or 10 are usually expected from the day's work of one man.

The days here understood are such in which the men may work about 12 hours.

In the following table C. stands for hundred.

42. A TABLE for constructing of Batteries.

Number of 24 pounders in battery.	Length of the parapet in yards.	Number of workmen to construct the battery.	Number of workmen's tools used at the battery, viz. shovels, spades, pickaxes, mattocks, &c.	Fascine-makers, each a bill and hatchet.	Fascines of 8 or 9 feet by 8 or 9 inches.	Fascines of 12 feet by 8 or 9 inches.	Fascines of 5 or 6 feet by 5 or 6 inches, made by the cavalry.	Pickets from 3 to 6 feet long, and about 1½ inch thick.	Mallets to drive the pickets.	Handbills, 2 for each embrasure, beside spare hatchets.	Planks for the platforms, 2 or 2½ inches thick.	Gunners to serve in the battery.	Soldiers to assist the gunners.	Powder for 100 rounds, at 12 lb. each per day.	Shot of 24 pounds for 100 rounds.
2	14	50	70	15	120	40	2 C	520	10	4	32	4	12	24 C	2 C
3	20	60	85	20	165	60	3 C	740	14	6	48	6	18	36 C	3 C
4	26	70	100	25	210	80	4 C	960	18	8	64	8	24	48 C	4 C
5	32	80	115	30	255	100	5 C	1180	22	10	80	10	30	60 C	5 C
6	38	90	130	35	300	120	6 C	1400	26	12	96	12	36	72 C	6 C
7	44	100	145	40	345	140	7 C	1620	30	14	112	14	42	84 C	7 C
8	50	110	160	45	390	160	8 C	1840	34	16	128	16	48	96 C	8 C
9	56	120	175	50	435	180	9 C	2060	38	18	144	18	54	108 C	9 C
10	62	130	190	55	480	200	10 C	2280	42	20	160	20	60	120 C	10 C
11	68	140	205	60	525	220	11 C	2500	46	22	176	22	66	132 C	11 C
12	74	150	220	65	570	240	12 C	2720	50	24	192	24	72	144 C	12 C
13	80	160	235	70	615	260	13 C	2940	54	26	208	26	78	156 C	13 C
14	86	170	250	75	660	280	14 C	3160	58	28	224	28	84	168 C	14 C
15	92	180	265	80	705	300	15 C	3380	62	30	240	30	90	180 C	15 C
16	98	190	280	85	750	320	16 C	3600	66	32	256	32	96	192 C	16 C

43. When

43. When batteries are erected at leisure, and are wanted to stand for some years, it is best to make them of stone or brick, or good loamy earth, according as the materials are nearest at hand, or can be most easily procured.

When made of stone, the thickness of the parapet is usually about 4 or 5 feet; but this thickness is varied, according to the quality of the stone, or to the size of the cannon that may be brought by an enemy to fire on it.

Parapets of brick are of 5, 6, 8, or even 10 feet thickness, according to the goodness of the materials, or the service it is to endure; and the angles are generally of stone.

A parapet made of good earth, and 18 or 20 feet thick, with the surface covered with green turf, will resist the injuries of the weather for several years, and stand the shock of an enemy's cannon the best of any.

44. As these perpetual batteries are generally raised somewhat above the level of the adjacent land or water which they are to command; so it is usual to make the floors of the embrasures sloping, the drip being on the outside, about a foot or foot and half below the sill of the inner opening, that the cannon may be pointed downward.

When the embrasures are cut through an earthen parapet, they are commonly lined with brick; or at least the angles are made of masonry, these parts being the most subject to be injured by the weather.

The best embrasures are those made with a neck, by which a part of the opening becomes more contracted, and consequently is better adapted to preserve the gunners and cannon from the enemy's shot, than when the cheeks of the embrasures are made straight.

45. Although the axis or middle line of an embrasure should, if possible, be at right angles to the length of the parapet, yet it may sometimes be necessary to have them oblique. When this happens, the inside of the parapet is notched, or so cut away, to leave proper room for the front of the platform, that the wheels of the carriage may be drawn up against the inner opening for the axis of the gun to lie in the axis of the embrasure; but then the outside of the parapet is to be strengthened, to compensate for what is cut away within.

The foregoing particulars, relating to embrasures, will be sufficiently illustrated by the following precepts for their construction.

46.

To construct the Plans of embrasures.

FIRST. *For the plain embrasure, Plate XV. Fig. 4.*

- 1st. Draw the axis AB perpendicular to the parapet.
- 2d. For the front opening, make $AC = AD$, each from 4 to 5 feet.
- 3d. For the inner opening, make $BF = BE$, each from 1 to $1\frac{1}{2}$ feet.
- 4th. Draw FD, EC, for the cheeks of the embrasure required.

47. *SECONDLY. For the necked embrasures. Plate XV. Fig. 5.*

1st. Having drawn the cheeks for a plain embrasure as before; from B, the middle of the inner opening, draw BC, BD.

2d. In the axis AB, take $BG = 2\frac{1}{2}$ or 3 feet; through G draw IH at right angles to BA, cutting BC, BD, in H, I, and join EH, FI.

Then DIF, CHE, are the angular cheeks, IH being the neck or narrowing of the embrasure.

48. *THIRDLY. For an oblique embrasure. Plate XV. Fig. 6.*

1st. Draw the axis *ab* in the direction where the gun is to command, and through any convenient point I, taken in *ab*, draw NN at right angles to *ab*.

2d. Make $IN = 4$ or 5 feet for the front opening, $IP = 1$ or $1\frac{1}{2}$ feet for the inner opening, and $IQ = 4$ feet for the front of the platform.

3d. Through N, P, Q, and parallel to *ab*, draw NC, ND, cutting the front of the parapet in C, D; and Pp, Qq, cutting the inside of the parapet in q, q.

4th. Through q draw *qr* parallel to NN, cutting the former lines in F, B, E, r; join ED, FC, and draw *rs* parallel to a line through B and C.

Then the space *qrs* being cut away, the wheels of the carriage can knock against the line *qr*, and the axis of the gun will lie in the line *ba* intended for the axis of the embrasure.

It is evident that the parapet is considerably weakened by the cuts for these oblique embrasures, and therefore should be strengthened on the outside.

49. *When the embrasures are to be expressed in the parapets of a plan drawn from a small scale, it is done thus. Plate XV. Fig. 8.*

On the inside of the parapet *as*, lay off as many times 6 yards, in the points *c, c, c, &c.* as the length of the parapet will admit, unless you are restrained by particular circumstances; and from the points *c, c, c, &c.* draw lines to the front of the parapet, dividing it into parts of 3 yards each; then taking the parts opposite to the points *c* for the fronts of the embrasures, the other parts will represent the fronts of the merlons.

Shade all the merlons, leaving white angular spaces to express the embrasures, and strengthen the inner line of the parapet and the front lines of the merlons.

50. *Of the profiles of batteries. Plate XV. Fig. 7.*

Let the ground line of the battery be AB, BD that of the parapet, the inner slope of which DH is formed by making $Da = 1\frac{1}{2}$ feet, and the perpendicular $aH = 6$ or 7 feet; the crown of the parapet HI is formed by making *bI* a foot or two lower than *aH*; and the front of the battery IB is found by making $bB = \frac{2}{3} bI$, when of earth, or $= \frac{1}{2}$ of *bI* when of masonry. Making $DC = 2\frac{1}{2}$ or 3 feet, gives *c* the fill of the embrasure, the floor of which CG is to dip a foot or two below the level line CF.

The platform DE is 18 or 20 feet, the tail E rising about 6 inches above the level line AB, the lower double line represents the sleeper laid lengthwise, and the upper double line shaded with the lines across, express the ends of the planks laid on the sleepers.

A gun on its carriage, with the wheels against the knocker at D, is annexed to the figure, to assist the learner's apprehension.

SECTION

SECTION III.

Of additional works.

51.

Of Ramps.

When a battery is raised above the level of the ground it is built on; there must be made gentle slopes for the cannon to be drawn up and down, and also for the easier communication of the troops posted there; these slopes, to distinguish them from the slope usually given to elevated works for their better security of standing, are called *Ramps*.

The base of the slopes commonly given to earth-banks for their support, is on the inside about a foot base for a foot of height, and on the outside is about 8 inches on a foot, or $\frac{2}{3}$ of the height; that is, they rise 12 inches, on 8 inches of base. But for the slopes of ramps, the rise is only about 2 inches on 12, or the length of the ramp's base is six times the height, and this is general, for the draught of carriages; but foot-ways need not be of so gentle a slope, a rise of one foot in three may do well enough; or, instead of ramps, stairs may be, and commonly are, used for the passage of the foot.

The breadth of a carriage-ramp is usually about 9 or 10 feet, that breadth being sufficient for the carriage and foot-way beside; but those for foot-passage only need not be above 3 or 4 feet wide.

Ramps may either rise on the side of an elevated work, or against a salient angle of that work, or on each side of an entering angle: their representations in plans may be expressed as in the following constructions.

52. *To construct a Ramp on the side of a bank.* Plate XV. Fig. 9.

Let *xx*, *zz*, be lines expressing in a plan the slope of a bank equal to its height, which suppose to be 12 feet.

1st. Through *A*, the point where the ramp is to end, draw *CB* perpendicular to *xx*, and make *AC* of about 10 feet.

2d. In *zz* take *BD* = 4 times *AB*, or 16 yards; through *D* draw *AE*, and through *C* draw *CF* parallel to *AE*, cutting *xx* in *G*, and *zz* in *F*.

3d. Through *F* draw, at right angles to *GF*, the line *fE*, cutting *xx* in *f*, and *AE* in *E*; join *BE*, and the lines *GF*, *EA*, *EB* express the ramp.

It is sometimes proper to have ramps rise on either hand for the convenience of carriages coming from the right or left; but they must then be so far asunder, that should a carriage be drawing up each at the same time, the horses of one may pass clear of those of the other.

To construct a Ramp in a salient angle of a bank. Plate XV. Fig. 10.

53. FIRST METHOD. This is done in the same manner as in the side of a bank; observing that the end *A* is taken 6 or 7 yards from the salient angle, when a ramp is to be constructed on both sides; otherwise the ramp may end at the salient angle *x*.

54. SECOND

54. SECOND METHOD. Fig. 11. 1st. From x draw a line xN , bisecting the salient angle; make xN ± 6 times the height, or equal to 12 yards, and on both sides draw a parallel line QR at the distance from xN of half the breadth of the way; suppose at 5 feet distance from xN .

2d. Bisect the angle xQR with the line QY , cutting the line zz in Y ; join YR , and the plan is formed.

55. THIRD METHOD. Fig. 12. From x the salient angle, with a radius of 6 times the height, suppose of 12 yards, describe the arc IL ; and with 5 times the height, or ten yards, describe the arc KK , cutting ZI in O , and draw OP parallel to KL .

Make xM ± 2 or 3 yards, and draw the curved lines MO , MP , which in plans are best done by hand; or else draw right lines from M to O , and from M to P , and the plan of the ramp is made.

56.

Of Barbets.

It often happens, that by raising the floor of part of a battery the guns placed on it have an advantageous command over some part of the neighbourhood; and when the guns thus raised fire over the crown of the parapet without any embrasures, it is called an OPEN BATTERY, or *Battery en barbe*, or plainly a BARBET.

These barbets may be made either in a curtain, or at the salient angle of a flanker. They should always be $2\frac{1}{2}$ or three feet lower than the crown of the parapet, and about 8 or 9 yards broad at the top, with a proper slope to the base, of a length suitable to the number of guns to be mounted on them, allowing about 5 or 6 yards for each, and have a proper ramp at each end to ascend them by.

57. To give a farther illustration of this article, here is added an explanation of the plan, and of the profile through the line BC . Plate XV. Fig. 13, 14, 15.

Let $PQRVX$ be a common bank of a line, the parapet of which is $RSTV$; the inner slope RS being about 6 or 7 feet higher than QR : then the bank $mnoR$, raised so high that the cannon can fire over the crown of the parapet ST , is the *barbet*, the height of which ap is about 3 or 4 feet.

On the top of the barbet a platform is raised as in other batteries.

Let the fig. 14, 15, represent part of the plan of a line, and one of its flankers or of a battery constructed in such a form; where Aa is the length of the barbet or raised battery, suited to the number of guns to be used, which are to be drawn up the ramps put at the ends; the breadths being about 8 or 9 feet, and the length ab about 7 or 8 yards.

58.

Of Cavaliers.

A cavalier is a battery raised above the other works, and covered by a parapet with embrasures.

Cavaliers are of various shapes, such as square (Plate XV.) fig. 17, or round, fig. 16, or like a horse-shoe, or a plane line; but when they are constructed in flankers, as is usually the case, fig. 18, they are of a like

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figure to that flanker; leaving a space of about 8 or 10 yards or more, between the parapet of the flanker and the outline of the cavalier.

They should be faced with earth, or plank of brick, but not with stone; because the splinters knocked off by the enemy's cannon would greatly annoy the troops, that may be posted in the line below the cavalier.

Any other particulars will be sufficiently known from the figures; observing, in the plans, to represent their outside limits by a double line, to express the sloping of the earth, and to put a ramp in the gorge.

59.

Of Traverses.

A traverse is a bank of earth thrown perpendicularly across a line, or other work, to prevent the enemy's cannon from taking that line.

These traverses may be from 12 to 18 feet thick, in order to be cannon proof, and their height about 6 or 7 feet; or more, if the line is exposed to any eminence from which the enemy has a command.

And to preserve a communication a passage of about 5 or 6 feet wide must be left at one end of the traverse.

60. The different ways of constructing these works are readily seen by the figures in Plate XV. fig. 19, 20, 21, 22.

Thus at A, fig. 19, it is formed by two equal short banks, the ends of which jut one beyond the other about 3 or 4 feet, leaving a passage of about 6 feet.

At B, C, and fig. 20, 21, the end of the traverse juts about 2 or 3 feet into the parapet, beside the passage. But as this greatly weakens the parapet, it is to be practised only in such places where there is sufficient thickness left; where nothing can be spared from the parapet, the traverse may be made as at E and F, fig. 22.

If any part of a work, thus shut in by one or more traverses, is likely to be defended by the musketry, then it is proper to add to the traverse one or more foot-banks within the defence, for the troops to mount on, when they want to fire over the traverse, leaving the upper foot-bank $4\frac{1}{2}$ feet below the crown of the traverse.

61.

Of Palisades.

Palisades are straight wooden stakes about 9 or 10 feet long and about the thickness of a middle-sized leg, but of a triangular or rectangular shape, according as they are of cleft quartering, or sawed stuff; and have one of their ends pointed. Their use is to form a line before those places, that are most likely to be taken by surprize.

The best are those made of oak, but where this is wanted, or on emergent occasions, the best are those which can most conveniently be procured.

In planting palisades it is usual to sink about three feet of them into the ground, the thick end downwards, and the pointed end upwards, and to set them about four inches from one another; the whole is braced together by pieces nailed across them near the tops, and secured by thick posts at the distance of every four or five yards.

Palisades

Palisades are found to be a very good defence against an enemy not greatly superior, and destitute of cannon; for the defendants may freely use their small arms at the time they are half covered by the palisades; whereas the assailants being quite exposed, attack with the disadvantage of at least two to one.

62.

Of Barriers.

A barrier is a kind of fence or gate serving to shut up the roads or passages in works of any kind, to prevent their being carried by surprise: they are of various kinds; as

1st. A strong chain drawn across the passage, at about $3\frac{1}{2}$ or 4 feet above the ground, and fastened at each end to an upright post.

2d. A beam laid horizontally across two upright posts.

3d. A BAR-GATE hanging by hinges to an upright post.

4th. A CHEVAUX DE FRISE, which is an horizontal beam usually cut with 6 sides, each of which is armed with iron spikes set within five or six inches one of the other. This beam is supported at each end by an upright post.

5th. A TURNSTILE, which consists of two or three pieces of timber framed crosswise, making four or six rays like the spokes of a wheel; this frame is put on a post in the middle of a passage to turn horizontally, so that two of its rays always stretch across the passage, and prevent more than one person at a time from passing the same way.

6th. A HERRISON, which is a chevaux de frise, turning horizontally on a post in the middle of a passage like a turnstile.

7th. KLINKETS are strong doors or gates made like palisades, and are hung and fastened as other gates are.

63.

Of Redoubts.

A REDOUBT is usually a temporary work thrown up to strengthen the lines which shut up, or secure a *pass*. They are usually figures of three, four, five, or six sides, encompassed with a ditch and a bank of earth.

The bank encompassing such works generally consist of two parts, called *rampart* and *parapet*.

64. The RAMPART is a large bank surrounding a work or place, of a height sufficient to cover the habitable parts of the houses (if any) from a direct fire of the enemy; or to raise the defendants so, as to command the neighbourhood; and of a thickness sufficient to resist the efforts of an enemy's cannon for some time.

65. The PARAPET, or breast-work, is a bank raised on the rampart close to its outer edge, to cover and defend the troops posted behind it, on the rampart.

66. On those sides of the work likely to be attacked, the parapet is cut into embrasures and merlons, of the same size and shape as has been shewn at arts. 35, 46,

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Against every merlon a *foot-bank* is raised on the inside for the musketry to stand on, when they are to fire over the crown of the parapet.

To every embrasure a platform is to be fitted, either of planks, as shewn in art. 36, or of stone, as described in art. 43.

When these redoubts are intended to defend lines or intrenchments, their faces or fronts should be so placed, that the shot discharged from them may fly directly to the front of those lines; for hereby the enemy may be so galled in flank, as to find it necessary to attack the redoubts, and so either weaken his attack on the lines, or cause him to lose time. But when redoubts are built more particularly to defend the spot on which they stand, their faces must front the places from which they may be battered, and also command the ways by which they may be approached.

67. The inner sides of square redoubts are usually between the limits of 12 yards and 32 yards; and when they are to be defended by musketry, the number of men necessary to the defence may be thus determined.

RULE. *Half the side squared gives the number of troops.*

EXAM. In a square redoubt, one side of which within is 24 yards, required the number of troops necessary for its defence:

Half of 24 is 12: then the square of 12 is 144 for the number of men.

AND, Twice the square root of a given number of men shews the length in yards of the side of a square redoubt proper to contain them.

Thus to contain 100 men, the square root of which number is 10, the side of the square redoubt must be 20 yards.

68. *To construct a square redoubt.* Plate XV. Fig. 23.

1st. Mark out a square, the side of which is adapted to the number of troops allotted for the defence; as AB for the inside of the rampart.

2d. About this square, at the distance of 10 or 12 feet, describe another square, the side of which CD is the inner boundary of the parapet.

3d. Make a parapet about 9 or 10 feet thick, the outline of which is the line EF; leave a berm about 3 or 4 feet broad, the side of which is GH, and dig a ditch about 16 feet wide, and about 6 or 7 feet deep, which let be rounded before the angles of the redoubt.

4th. Make the rampart from 4 feet to 9 or 10 feet high, according to circumstances; let the parapet be 6 or 7 feet higher, and let the foot-bank be $4\frac{1}{2}$ feet lower than the crown of the parapet.

5th. On the side most secure from the enemy make a bridge across the ditch, and a passage through the rampart. The breadth of this way should be about 4 or 5 feet, if the defence is to be by musketry only; but 9 or 10 feet if cannon are to be used; and in either case the passage is to be shut up by a strong gate.

But if the redoubt is to be defended by cannon, both the rampart and parapet should be at least 5 or 6 feet thicker.

69. As it is customary for troops to present their breasts to the parapet, and then fire direct before them, there will be a very considerable space before each angle of the work, that will be in a great measure without any defence. To remedy this defect in these works, it has been proposed to round the inside of the angles of the parapet, and post three or four men there to defend the angle; for more cannot well be applied. But this appearing also defective, Mr. Clairac has shewn an ingenious method to make the fire pretty nearly equal in all parts; which is done by cutting the inside of the parapet into notches, whose two sides, of a yard each, are at right angles to one another, and make half right angles with the sides of the work; the manner of which and its defence, will be plain from fig. 23. where the lines with dots at the ends represent the fire three different ways from the same side.

There are in many Treatises of Fortification directions to make a kind of temporary works called SCONCES, or FIELD-FORTS; some of which being pretty well contrived for defence, will be here explained; but one species of sconces, called STAR-FORTS, are such *wretched baubles*, that nothing more will be mentioned of them here, than that their plans are pretty things to flick on children's kites.

70. *To construct a Flanked Redoubt.* Plate XV. Figs. 24, 25, 26.

Having described the inner figure, where AB is an inner side of the redoubt, suppose of about 18 yards;

Parallel to this figure, at the distance of about four or five yards from it (or more if necessary), describe an outward figure, the sides of which are ED, EF, &c.

Divide each side, as ED, EF, &c. into three equal parts, one of which is EI, EL, &c.; and in these sides prolonged take DG, EH, &c. each equal to one of those three parts.

From the points G, H, &c. thus found, draw the lines of defence to the angles of the outward figure, as HD, &c.

From the points I, L, &c. draw the flanks, IK, LM, &c. perpendicular to the sides, ED, EF, &c. meeting the lines of defence in K, M, &c.

Or, *The flanks may be thus drawn.*

In the line DI continued towards E, take IP equal to twice IE. And from P, as a center with the radius PI, cut the line of defence in K, and draw the flank IK.

Then to each face (HK), flank (KI), and curtain (IG), make a parapet of about 7 feet thick (or more if necessary), which is expressed in the plan by lines drawn at that distance on the inside of the several parts.

Leave a proper berm of about 4 or 5 feet broad, and make a ditch of about 5 or 6 yards wide, the outer line of which, or counterscarp, is to be parallel to the faces and curtains only.

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A redoubt thus constructed is more capable of defence than one without flanks: for the curtain IG is well defended by the flank IK; and the face HK has some defence from the part DG.

71.

Of Redans.

A REDAN is a fortified line broken into several curtains and flanks; the defences of the flanks being all directed one way.

This is a very good work for the defence of any passage, such as a hollow way, a road, a river, or a harbour's entrance.

If the defence is intended chiefly for cannon, the distance of the flanks from one another should not exceed 300 yards, that being about the point-blank flight of a musket shot. But if the defence is chiefly intended for musketry, the distance of the flanks may be about 50 yards or less. In general the distance of the flanks should be regulated according to the number of them intended to be placed within the length of the line. The length of each flank should be about 15 or 18 feet, in order to admit one gun; but if more cannon than one are to be put in a flank, the flanks must be made proportionally longer.

And if the flanks are made about two or three feet lower than the curtains, there will be no danger of the troops posted in the salient angle of one flank, being hit by those in the entering angle of the flank next behind.

72.

To construct a Redan.

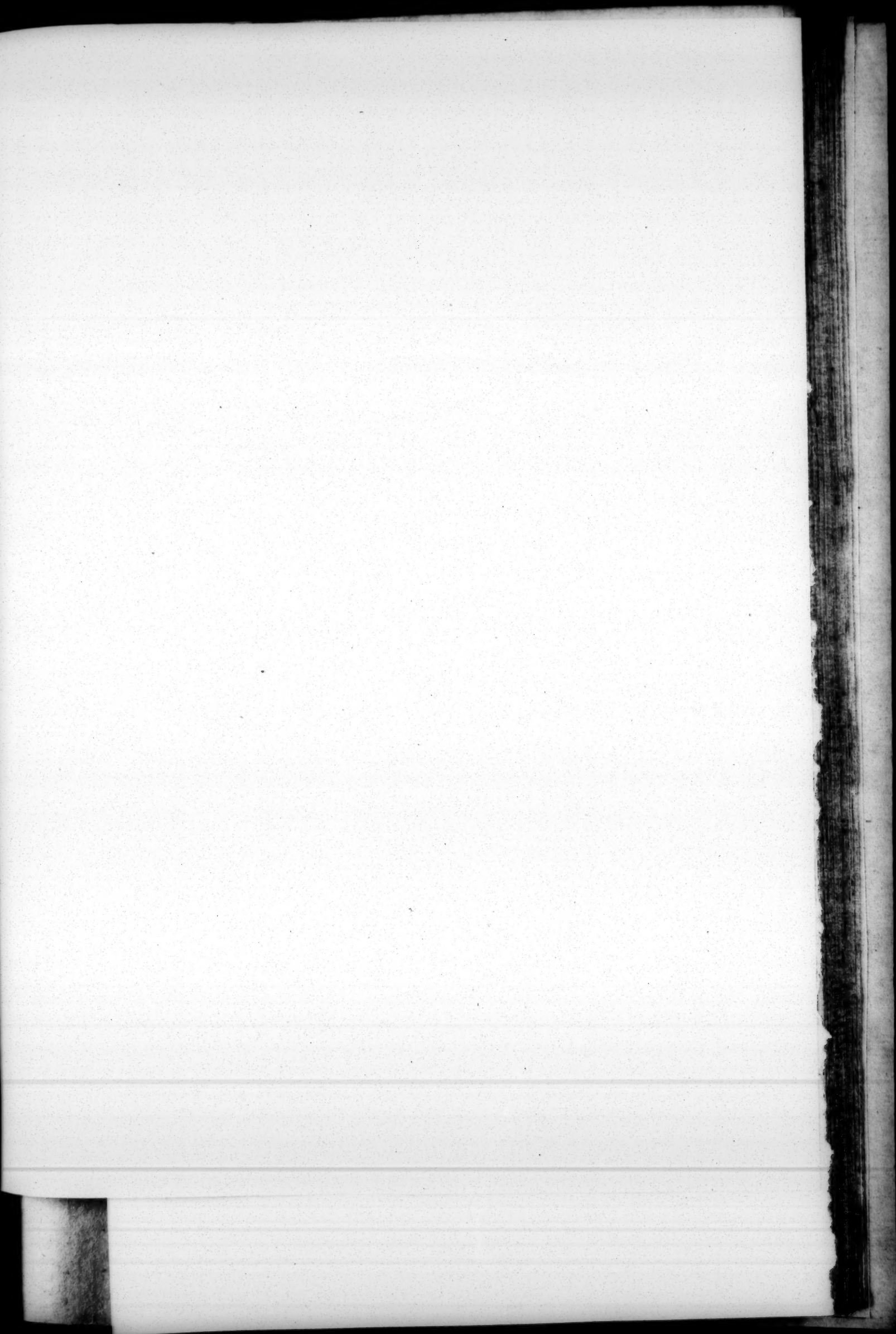
In the front line take the equal spaces AB, AB, &c. of the length proposed for the distance of the flanks, as suppose 50 yards; draw the perpendiculars AC, BD, of 18 feet each, and draw the faces BC, AD.

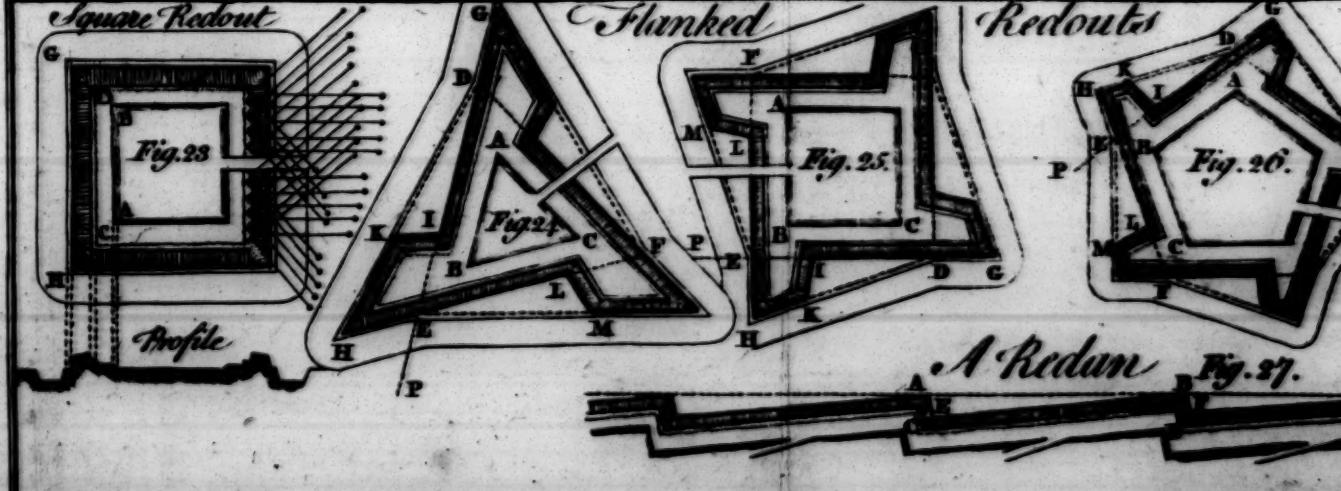
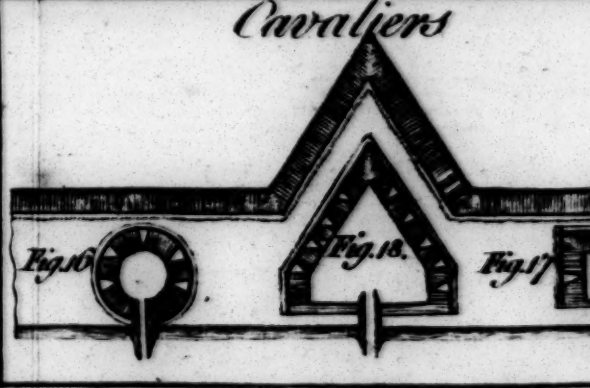
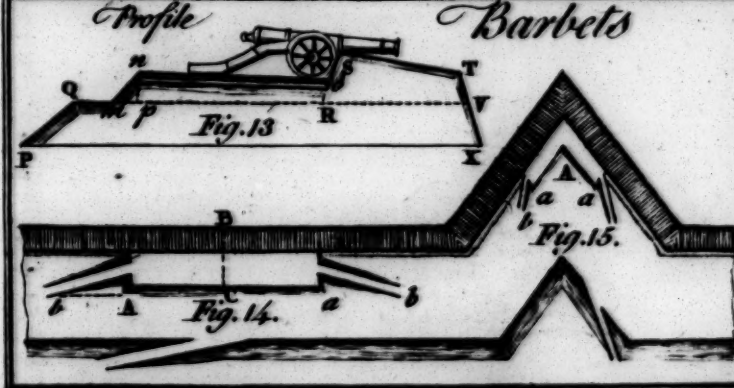
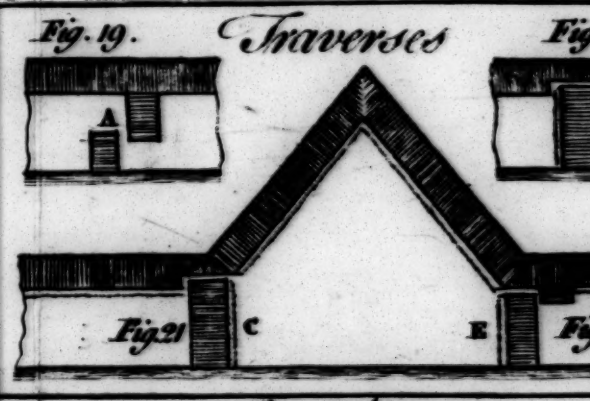
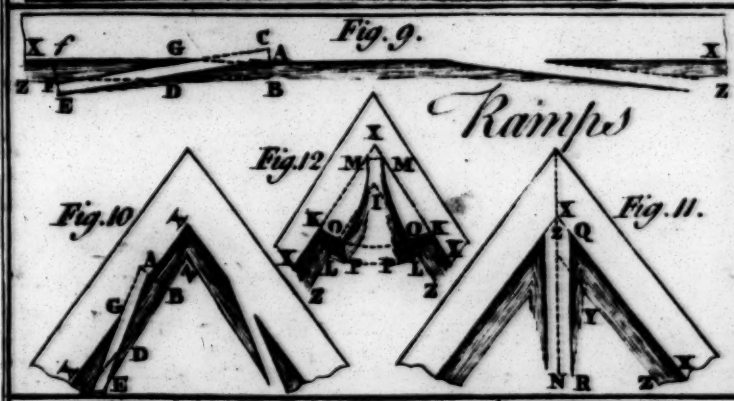
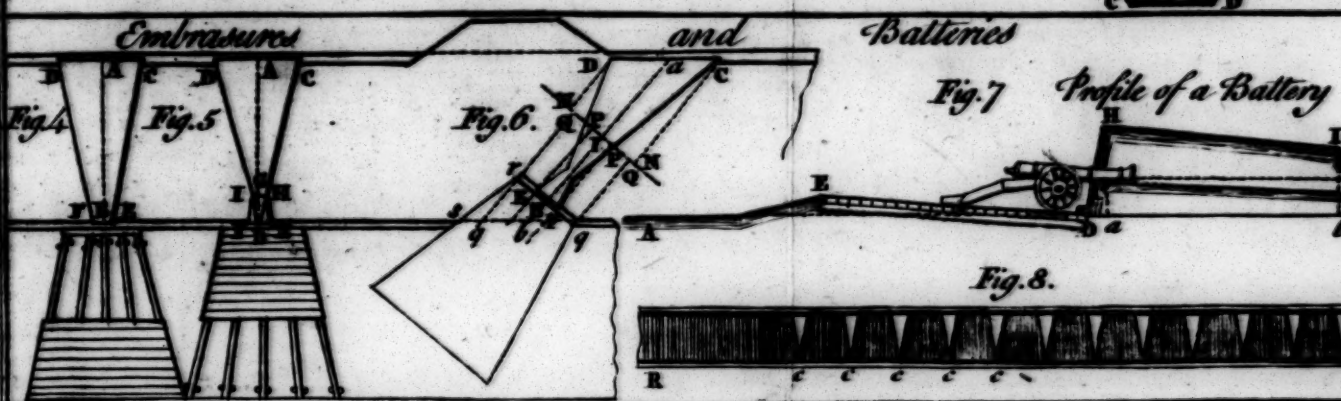
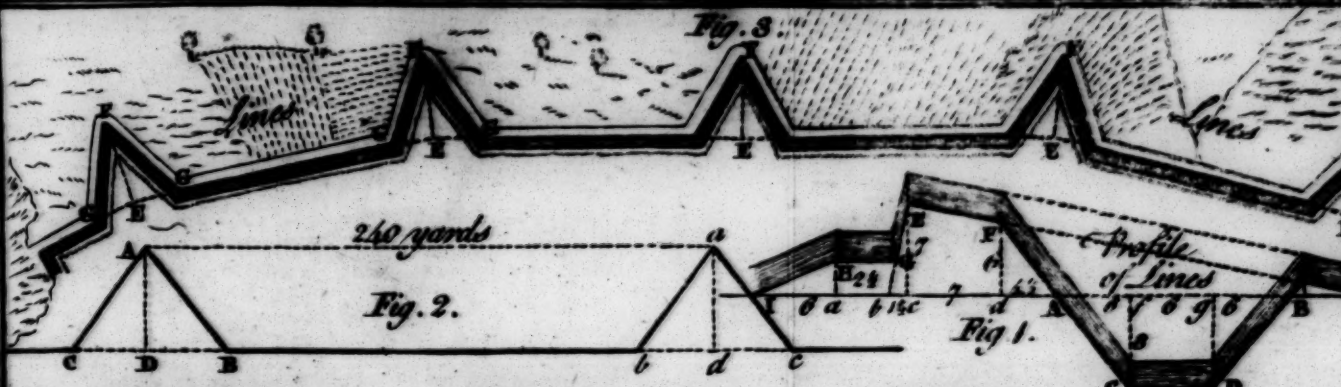
From the salient angles A, B, draw the flanks AE, BF, at right angles to the faces, and the master line AEBFAE will be constructed.

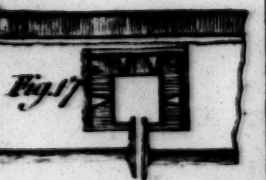
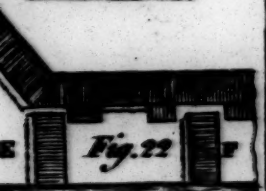
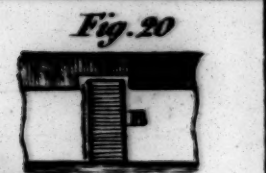
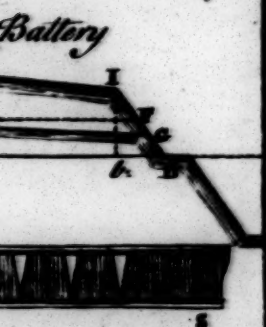
Make a rampart, parapet, and foot-bank; ramps in the curtains, an embrasure in each flank, and as many in each face as convenient.

The thickness of the parapet, if of earth, may be from 9 to 12 feet; but if of masonry, about 4 or 5 feet will do.

SECTION







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SECTION IV.

Of the Fortifying of Towns.

Towns are fortified by surrounding them with a rampart, moat and outworks.

73. The **RAMPART** of a town is a large bank of earth surrounding the place, of a height sufficient to cover the habitable parts of the houses from the direct fire of an enemy; and of a thickness sufficient to resist the efforts of his cannon for many days.

The rampart at certain distances, within the reach of musket shot, should have works projecting outwards, either contiguous to the rampart, or detached from it; and these projections are to be so contrived, as to flank or defend one another.

Projecting works contiguous to the ramparts are called *bastions*, and those detached from it are called *outworks*.

74. A **BASTION** is a projecting work consisting of four lines; namely, of two **FACES** forming a salient angle; and of two **FLANKS**, which join one to the end of each face, and have their other ends joined to the rampart.

75. The **CURTIN** is that part of the rampart which lies between two bastions.

76. The **PARAPET** is a breast-work ranging quite round the faces, flanks, and curtains; of a height and strength proper to cover the troops posted on the rampart.

77. The **MOAT** is a large ditch dug on the outside of the rampart and some outworks, quite round the place; the earth that comes out of it serves to make the ramparts, parapets, and other elevated works.

The **SCARP** is that border or wall of the moat next the place, and the **COUNTERSCARP** is the opposite border or wall.

78. The **COVERED-WAY** is a sort of passage or street running quite round the moat next the counterscarp; and is covered on the side next the country by a bank or parapet.

79. The **GLACIS** is a gentle slope of earth descending from the parapet of the covered-way towards the country.

The *head of the glacis* is the highest part of it, or the top of the parapet next the covered-way. This part is sometimes called the counterscarp; but the soldiery usually call the covered-way and glacis together the counterscarp.

80. The **OUTWORKS**, or those detached from the rampart, are of various forms and uses; some to cover the principal parts of the rampart, and to retard the enemy's approaches towards the town, and others to secure those places, which, if neglected, might be of advantage to the besiegers.

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81. *The names of the principal Parts of the Plan of a Fortrefs. Plate XVI.*

The figure HFBMN represents the plan of a bastion. Fig. 4.

<i>ag</i>	the thickness of the rampart.
<i>ad</i>	the breadth of the parapet.
<i>mm</i>	the moat, ditch, or foss.
<i>aaaa</i>	the covered-way.
<i>bbbb</i>	the glacis.

82. *Of the principal Lines.*

The line AB represents the exterior side of the polygon, and LA its radius.

IK	the interior side	and LI its radius.
IA	the capital	CD the normal.
GH	the curtain	AH the line of defence.
GI	the demi-gorge, the breadth	HN the gorge.

The line HF represents the flank } of the bastion.
And BF the face }

83. *Of the principal Angles.*

The angle ALB represents the angle of the center.

$\angle AAB$	the angle of the polygon, or $\angle$ of the gorge.
$\angle EGH$	the angle of the curtain, or $\angle$ of the flank.
$\angle GEA$	the angle of the shoulder.
$\angle FBM$	the angle of the bastion, or flanked angle.
$\angle BAH$	the diminished angle.
$\angle ADB$	} the exterior flanking angle; or the angle of the tenail.
$\angle EHG$	
<i>apa</i>	the angle of the counterscarp.

84. *The names of the principal parts of the Profile of a Fortrefs.* Supposed to be taken through the line PR, Fig. 6.

The line Aa represents the thickness of the rampart at its base.

AR	the inner slope	} of the rampart.
BR	the inner height	
BC	the walk	
CD	the slope, and DE the top of the foot-bank.	
EF	the inner face or slope	} of the parapet.
FG	the top or crown	
GH	the outer slope or front	
HI	the face of the wall, called the scarp.	
IK	the breadth of the moat.	
KL	the outer wall of the moat, or counterscarp.	
LM	the breadth of the covered-way.	
MN	the slope, and NO the top of the foot-bank.	
OP	the slope of the parapet, or inner face of the glacis.	
PQ	the gentle slope, and P the head of the glacis.	

Military

Military works of defence should be conformable to the principles which have from time to time been collected and established as fundamental propositions; such are the following.

85. GENERAL PRINCIPLES, *usually called* MAXIMS.

I. The plan of every place that is to be fortified, ought first to be circumscribed with one of the most convenient polygonal figures that can be fitted to that place, and this polygon to be fortified.

II. The more regular the circumscribing polygon is, the better.

III. It is a disadvantage to be under a necessity of extending the works about a fortress.

IV. Every side of the polygon, as much as is possible, should be equally fortified; that the enemy may not have it in his choice to attack a part more weak than the rest.

V. All works ought, as much as is possible, to be easy to build, hard to destroy, and not difficult to be repaired.

VI. The works about a fortress should be so contrived as to cover the defendants, discover the approaches of the enemy, and be adapted to the common weapons of defence.

VII. Each work should be defended from as many as may be, and liable to be attacked from as few places as possible.

VIII. These works made to defend one another should be sufficiently large to contain the troops and cannon necessary for that defence.

IX. Works which are to flank one another ought not to be at a greater distance than the point-blank sight of a musket-shot.

X. The works farthest distant from the body of the place should ever be lowest, that they may be commanded by those that are nearer.

XI. None of the works should, if it can be helped, be beyond the point-blank reach of the cannon within the town.

XII. Wet ditches are preferable for small places, dry ones for large places.

XIII. Bastions with large flanks and large gorges are most esteemed.

XIV. The flanked angle of a bastion should not be much less than a right one, but are better when obtuse, not exceeding 120 or 130 degrees.

XV. The faces of bastions should not differ much in length from 100 yards.

XVI. A curtain should not be much longer than 180 yards, nor much shorter than 100 yards.

XVII. The angle of the curtain should be between the limits of 90 and 100 degrees.

XVIII. The point-blank sight of a musket-ball is about 300 yards, or within the limits of 240 and 360 yards; and that of a battering cannon is about 1200 yards.

XIX. Battering cannon will drive a ball 14 or 15 feet into a bank of common earth at a distance of 300 or 400 yards.

From the foregoing maxims constructions have been made for all the regular polygons from four to twelve sides inclusive; and the quantity of the several lines and angles have been obtained from trigonometrical operations; the results of which are contained in the following table.

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86. A TABLE shewing the measures of the principal lines and angles in all regular Fortresses from four to twelve sides inclusive.

Calculated from the exterior side, normal and face being taken as known quantities in yards.

Names of the polygons.		Square.	Penta-gon.	Hexa-gon.	Hepta-gon.	Octa-gon.	Nona-gon.	Deca-gon.	Undeca-gon.	Dodeca-gon.
The exterior side in yards.		360	360	360	360	360	360	360	360	360
Radius of exterior side in yards.		254,56	306,24	360,00	414,82	470,36	526,28	582,50	638,78	695,46
Interior side in yards.		231,00	247,90	261,26	272,44	280,06	285,86	288,52	292,60	296,20
Radius of interior side in yards.		163,34	210,90	261,26	313,96	365,96	417,86	466,90	519,36	572,14
Capital in yards.		91,22	95,34	98,68	100,96	104,40	108,42	115,60	119,42	123,32
Normal in yards.		45	54	60	64	68	72	78	82	86
Curtin in yards.		456,06	154,22	152,80	151,80	150,54	149,40	147,34	142,90	138,68
Flank in yards.		40,54	48,92	54,54	58,32	62,12	65,92	71,66	73,96	76,18
Face in yards.		100	100	100	100	100	100	100	102	104
Line of defence in yards.		265,96	268,42	270,28	271,62	272,86	274,32	275,46	276,30	276,34
Demigorge in yards.		37,48	46,84	54,26	60,32	64,76	68,24	70,58	74,84	78,76
Angle of the center		90° 00'	72° 00'	60° 00'	51° 26'	45° 00'	40° 00'	36° 00'	32° 44'	30° 00'
Angle of the polygon.		90 00	108 00	120 00	128 34	135 00	140 00	144 00	147 16	150 00
Angle of the curtin.		97 01	98 21	99 13	99 47	100 21	100 54	101 43	102 15	102 46
Angle of the shoulder.		111 03	115 03	117 39	119 21	121 03	122 42	125 09	126 45	128 18
Angle of bastion, or flanked angle.		61 56	74 36	83 08	89 26	93 36	96 24	97 08	98 16	98 56
Diminished angle.		14 02	16 42	18 26	19 34	20 42	21 48	23 26	24 30	25 32
Exterior flanking angle.		151 56	146 36	143 08	140 52	138 36	136 24	133 08	131 00	128 56
Breadth of the foss, in yards.		30 yds.	30 yds.	36 yds.	40 yds.	40 yds.	40 yds.	42 yds.	44 yds.	46 yds.

By

By the help of this table, every thing relative to the master-line of any of these fortresses is readily constructed.

87. PROBLEM I.

To describe any of the polygons in the table.

FIRST. *To construct a polygon in a circle.* Plate XVI. Fig. 1.

- 1st. With the exterior radius of the given polygon describe a circle.
- 2d. Apply the exterior side equal to 360 yards within the circumference of that circle, from A to B, B to C, C to D, &c. as many times as the proposed polygon has sides.
- 3d. Draw the lines AB, BC, CD, &c. and the polygon will be constructed.

88. SECONDLY. *To construct a polygon upon the exterior side.* Plate XVI. Fig. 2.

- 1st. Draw the exterior side AB equal to 360 yards.
 - 2d. At the ends A, B, make angles equal to the angle of the polygon, and in that position draw the lines AE, BE, each of the length of AB.
 - 3d. At the points E, C, make angles as before, and in those positions draw the lines ED, CD, each of the same length as AB.
- And thus proceed until the polygon is constructed.
- Note,* The two last lines may be found by describing intersecting arcs D, with the radius AB, from the centers E and C.

89. PROBLEM II.

To fortify any regular polygon in the table.
Or, To draw the MASTER-LINE of a regular fortress.

FIRST. *From the exterior side.* Plate XVI. Fig. 3.

- 1st. Make the exterior side AB equal to 360 yards, and find its middle C.
- 2d. Draw CD at right angles to AB, and make CD equal to the normal.
- 3d. Through D draw the lines of defence ADH, BDG.
- 4th. Make the faces AE, BF, each of their proper lengths.
- 5th. Transfer the distance FE from F to G, and from E to H.
- 6th. Draw the curtain GH, and the flanks EG, FH.

This work being done for every front or side, the master-line of the fortress will be described.

This method is most fit, when the master-line is to be laid down on a place where there were no works before.

90. SECONDLY. *To fortify from the curtain.* Fig. 3.

- 1st. Make the curtain GH of its proper length, for the given polygon.
- 2d. Make the angles of the curtain HGE, GHF, as in the table.
- 3d. In the lines GE, HF, take the flanks GE, HF, of their proper length.
- 4th. Make the angles of the shoulders GEA, HFB, as in the table.
- 5th. Make the faces FB, EA, of their proper lengths.

This

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This method is proper to be used when a piece of an old fortification is to serve for a curtain to save expence.

91. THIRDLY. *To fortify from the interior side.* Fig. 3.

- 1st. Make the interior side IK of the length given in the table for the proposed polygon.
- 2d. From each end set off its proper demigorge KH and GI.
- 3d. On K and I as centers, with the extent of the capital, as in the table, describe arcs at B and A.
- 4th. On H and G as centers, with the length of the line of defence, as in the table, cut the former arcs in A and B.
- 5th. Draw the lines AH, BG; in which take the faces AE, BF, and draw the flanks EG, FH.

This method is useful when modern ramparts and bastions are to be annexed to simple walls surrounding a place.

In either of the above methods, the work here described for one front is to be applied to every front of the polygon; and it is recommended to the learner, that he apply the precepts given for one front to a complete polygon; and should a frequent repetition of these operations to a whole polygon become disagreeable, they may be done only on two fronts, which may be thus drawn.

Draw a capital line AL; make the angles LAB, LAA, each equal to half the angle of the polygon; and make the sides AB, AA, each equal to 360 yards.

92. PROBLEM III.

To construct the plan of a bastion. Plate XVI. Fig. 4.

- 1st. Draw a capital line BK, and make the angles MBK, FBK, each equal to half the flanked angle.
- 2d. Take the lines BF, BM, each of the length of the face.
- 3d. At the points F, M, make the angles of the shoulder BFH, BMN.
- 4th. Make the lines FH, MN, each of the length of the flank.
- 5th. At the points H, N, make the angles FHG, MNa, equal to the angle of the curtain, and draw the pieces of the curtain HG, Na.

This problem may be found useful on many occasions; particularly when the drawings of works in a bastion are to be represented with that bastion only, on a large scale, therefore it was here introduced, more especially for beginners, who are apt to be somewhat puzzled about constructing part of a work, independent of the whole.

93. PROBLEM IV.

The master-line of a fortress being given; to draw the plan of the rampart. Plate XVI. Fig. 5.

- 1st. Draw the lines *ag* perpendicular to each face, flank and curtain.
- 2d. In each of the lines *ag* take $ag = 24$ yards, $ab = 20$ yards.
 $ac = 8$ yards, $ad = 6$ yards.
- 3d. Through

3d. Through the points d, c, b, g , draw lines parallel to the master-line; that is, to each face, flank, and curtain, intersecting one another.

Then the breadth of the rampart is represented by $ag = 24$ yards.

of the parapet by $ad = 6$ yards.

of the foot-bank by $dc = 2$ yards.

of the walk of the rampart by $cb = 12$ yards.

And of the slope of the rampart by $bg = 4$ yards.

The breadths of these parts of the ramparts are sometimes different, according to the quality of the earth, or other materials the work is to be built with.

Sometimes the bastions are made solid; that is, the rampart fills up the whole space contained within the faces, flanks, and neck. The plans of such are represented by continuing the pair of lines bg , forming the inner slope of the rampart, against the adjacent curtains, till they meet the capital in the breast of the bastion, as at R ; but then this pair of lines is to be omitted against the flanks and faces of such bastions.

In plans drawn from a large scale it is usual to express the outside slope of the rampart by a pair of lines; that is, by drawing a parallel to the master-line about five or six feet distant from it on the outside.

The master-line is to be drawn the thickest; the inside of the parapet something finer; and the other lines as fine as they can be drawn.

94. Before any of the lines are drawn in ink (for it should be remarked that every thing is first to be drawn in black lead pencil), let the ramps be put in the inner slope of the rampart (52); the embrasures in the parapets of the flanks (46); the barbets in the salient angles of the bastions, fig. 6. with their ramps (56); and the cavaliers, if any are to be, in the solid bastions, fig. 7. with their ramps and embrasures (58).

All these several parts being laid down with black lead pencil, let the lines be neatly drawn with Indian ink, taking care not to draw them beyond their proper terminations; for wherever superfluous ink lines are scraped off, the plans will never look well when they come to be washed with any colour.

When the plan is to be washed, that is, coloured with tints of Indian ink or other colours, leave the lower line of the inner slope of the rampart in lead pencil, which will make it appear softer when the drawing is cleaned off.

R E M A R K S.

95. In the middle of bastions, fig. 8. it is usual to build magazines for the stores of powder, bombs, and other fire-works, and also for the provisions for the troops, and lodging. For in these places they are not only more out of the way of doing damage to the town on an accident of blowing up, but they are also nearer at hand to be transported to the several works where they may be wanted; and here the troops may securely take their rest when relieved from duty.

These

These magazines are usually built about 20 yards long by 12 broad in the clear, and about 8 feet high in the upright, besides the rise of the semicircular vault: the side walls are about 8 or 9 feet thick at the foundations, and about 8 at top; the end walls about 5 at bottom and 4 at top: and that they may be bomb proof, the work is about three feet thick in the *reins*, or just above the springing of the arch, and eight or nine feet thick in the crown or top; this is effected by building the roof sloping on the outside, like the roof of a house.

These buildings are sometimes strengthened on each side by buttresses 6 feet by 4; and in each side wall there should be left in the solidity of the wall vent-holes to air the magazine: these vents wind round a kind of shaft of about a foot square. In each gable end, a small window is made to give light.

96. Magazines may be either in hollow or solid bastions; care being taken in the latter to leave an area about their walls, if the place is subject to damps. There are those, who would have the magazines at the foot of the rampart along the curtains, in order (as they say) that the bastion, by being left clear, may be disputed with the enemy inch by inch at last; but as there are very few examples, since the modern practice of war, of such extraordinary resolution in the defendants after a breach is made, the reasons for having the bastions thus unincumbered with buildings, are rather ideal than real, and consequently can have but little weight. However, when the ditch furnishes earth enough, or it can be otherwise easily had, it has been the practice of the most celebrated engineers to make full bastions, especially if they were small and had narrow necks.

97. In the salient angles of bastions, fig. 7. such as the flanked angle, and the angles of the shoulders, it is usual to make little centry-boxes of wood or stone, to secure the centinels from the inclemency of the weather and random shot. They are furnished in the sides with loop-holes, to see what is doing in the ditch and covered-way, and also to fire through on occasion.

The plans of these centry-boxes may be either square, round, or pentagonal, and their floors are on a level with the walk of the rampart; their communication is by a passage of about 3 feet wide, bricked on each side, cut through the parapet.

The centry-boxes built of stone are usually ornamented with mouldings, and the arms of the prince or state.

98.

P R O B L E M V.

The master-line of a fortress being given, to draw the plan of the fofs and esplanade. Plate XVI. fig. 4.

1st. On the flanked angle B of each bastion, with the radius BC equal to the breadth of the fofs, found in the table, describe an arc CC.

2d. Lay a ruler to touch each arc at C, and the angle E of the nearest shoulder of the next bastion, and in that direction draw the lines CP, meeting one another in P.

3d. From the flanked angle of each bastion draw lines BQ at right angles to CP.

4th. In

4th. In each of the lines Bq , take $ca = 10$ yards (Fig. 4.)

$co = 12$ yards, and $cq = 60$ yards.

5th. Through the points, a, o, q , draw lines parallel to cp , meeting before the middles of the curtains at c and t (Fig. 3), and before the flanked angle of the bastions in v, x, y .

Then will bc represent the breadth of the fofs.

cq	of the esplanade.
co	of the covered-way.
ao	of the foot-bank.
oq	of the glacis.

The arcs cc represent the roundings of the fofs.

The lines cp the counterscarp.

xc the head

xy the ridges

st the vallies

And yt the foot

} of the glacis.

The head of the glacis is to be drawn strong, and all the other lines are to be fine.

99. When the plan is to be washed, if the foot of the glacis be drawn in lead pencil only, the termination of the glacis, or its concurrence with the adjoining lands, will appear more soft and neat.

In the colouring of the glacis it is usual first to lay a very light tint of colour over every plane, and then to strengthen the colour on every second plane, beginning at any salient angle; the strongest tint to be next the head of the glacis, and to be washed gradually off; so that the limits of the lightest shade shall lie in a diagonal line from the foot of the glacis at a ridge, to the head of the valley, as from y to s .

Give a light touch of the pencil or brush, with a middling tint of Indian ink, along the inside of the line, denoting the foot-bank.

Wash the borders of the ditch near the scarp and counterscarp, softening the edge of the colour with a brush wet with fair water; in wet ditches the colour used is distilled verdigrise; but in dry ditches use bistre.

The parapet is generally coloured with a middling tint of Indian ink.

100. By this method of drawing the counterscarp, all the fofs is seen from the flanks, and consequently is defended by them; which must be more advantageous than if the counterscarp was directed to any other part of the flank, the intercepted part next the shoulder being by it rendered useless for the defence of the ditch; nevertheless, if it were on any account necessary, the direction of the wall of the ditch may point within the shoulder by the thickness of the parapet of the face, and still the fofs would have the whole defence of the flank.

101. Fortifications in general would be very defective without fosses: for the wall or rampart need not be raised so high when there is a ditch, as they must be without one, to secure the place from surprizes by scaling, &c. Neither is a low wall so much exposed as a high one is in the modern methods of attack. Besides, a place is not so liable to the attempts of a surprize with a foss, as it would be without one; for the enemy, if discovered, may easily retreat while he is on a level with the country, which he would find some difficulty in doing from the bottom of a deep foss bounded

bounded by walls or banks nearly upright. Add to these, that the earth taken out of the ditch serves to make the ramparts, parapets, glacis, &c.

102. It may appear to some persons, that the broader and deeper a foss is, the better, as it would throw more difficulties in the way of the besiegers when they wanted to pass it; but some advantages are best waved, when, by taking them, greater disadvantages would ensue. For beside the great expence that the digging and removing so much earth would occasion, the enemy might see the foot of the wall at a greater distance in a broad ditch; and in a deep one, the cannon of the flanks could not dip low enough to defend the bottom. And on the whole, if the foss by its magnitude furnished more earth than was wanted; some inconvenience might arise in the disposing of the overplus.

103. Those fosses are best, which can be filled with water and drained at pleasure by the help of sluices or floodgates; because all the advantages that may be reaped either from a wet or dry foss, are by these means obtained: but as these cannot be had every where, the ditch must be adapted to the situation of the place.

In dry fosses a row of palisades is sometimes planted along the middle, either upright, or sloping towards the counterscarp 20° or 30° from the upright.

In some dry fosses, where water can be had, a trench called *CUVETTE* *n n* (Fig. 12.) is dug along the middle, of about 12 or 15 feet wide and 6 feet deep, for the water to run in.

The breadth of the foss, although unequal in itself, is reckoned from the flanked angles, before which it is always rounded; the depth here may be from 15 to 20 feet, and thence rise gradually to the middle of the curtain where the depth is 4 or 5 feet less.

Of Gates.

104. A GATE, in a fortified place, is a passage through the rampart, which can be shut up or opened by the means of *doors* and a *portcullis*.

105. A PORTCULLIS is either a HERSE consisting of strong pieces of timber framed like a lattice, the lower ends of the upright pieces being shod with pointed iron, and the whole frame let down by chains or ropes: or ORGUES, consisting of several long pieces of timber not framed together; each hanging by its particular rope or chain, the ends of which are wound round a windlass which lets them all down together.

The use of a portcullis is to stop the gateway in case of a surprize; and in this, the orgues are by much the best contrivance; for a herse may be broken to pieces by a *petard*, or by cannon shot: but should a beam in the orgues be struck off in the middle, the upper part will descend to supply the place of the part taken away.

Gates are either public or private.

106. PRIVATE or POSTERN GATES are those passages through the rampart by which the troops can go out of the town unseen by the enemy, when they pass to and from the relief of the duty in the outworks; or on any other occasion which is to be concealed from the besiegers.

107. PUBLIC GATES are the passages through the middles of the curtains, to which the great roads or public ways lead.

They are put in the middles of curtains, as being the best defended place in the out-line of the rampart.

The dimensions of a public gateway are usually about 13 or 14 feet high, and 9 or 10 feet wide, continued through the rampart with proper recesses for the foot-passengers to stand in while the wheel-carriages pass on. It is usual to ornament the front of the gateway on the outside with architecture either of the Tuscan or Doric order, and to cover the passage with a strong vault. Over the vault, close to the town-wall, is erected a building of about 18 or 20 feet square, in which is suspended the portcullis; and on the inside of the rampart there is generally raised another building, of about 100 feet in front and 30 deep, and high enough to contain one or two floors of rooms for one of the town-officers, the ground floor serving for guard-rooms for the troops who are on duty at the gates.

108. *To construct the Plan of a Gate with the adjoining Buildings.* Pl. XVI.
Fig. 9.

Let the line ac represent the thickness of the base of the rampart, and the middle line of the gateway; in which take these measures in feet: $af=4\frac{1}{2}$; $fr=6$; $rb=18$; $ci=30$; and $cm=15$: through these points, lines being drawn parallel to the curtain; take $fd=4\frac{1}{2}$; $fb=14$; $rg=9$; $ck=50$; and $kl=6$ feet, and complete the figure.

Then bg represents the plan of the frontispiece; gh of the portcullis room; ik of the arcade or guard-house; and lk is the breadth of the stairs to ascend the rampart.

The plan, to which these directions refer, is on the right-hand side of the plate.

109. *Of the disposition of the Streets and Buildings in a Fortress.*

When a new town is built and fortified, and all that relates to the rampart is fixed with regard to situation and size; then the plan of the streets is to be considered; and here some authors have thought it convenient to adapt the position of the streets to the climate the town is built in.

Thus in hot climates, they would have the streets run NE. and SW.; NW. and SE.; for then the streets will be shaded by the houses from the mid-day sun: In this manner *New Brissac*, part of *Malta*, and some other regular built towns are laid out. But in cold climates, they advise to place the streets so as to run north and south, east and west, in order to have as much sun heat as can be.

110. *To design a Plan of the Streets and Buildings.*

About the middle of the town describe a square, the sides of which shall be parallel to the position of the streets (already determined); this square is called the great place of arms, and the size of it should be proportioned

portioned to that of the town, and to the number of troops designed for its defence. Thus in a square, make the side of the place of arms about 90 yards; in a pentagon, about 100; a hexagon, 120; a heptagon, 140; an octagon, about 160 yards, &c. In this place of arms the troops parade, or are assembled for their daily exercise.

In the continuation of each side of the square draw streets about 10 yards wide; likewise through the middle of each side draw a street about 12 yards broad; cross these streets perpendicularly with others about 8 yards wide; make the parallel distance of these cross streets about 40 yards, and continue all the lines to the rampart.

It is not necessary, that the middle streets going from the great place of arms *L* should terminate directly against the gate *E*, fig. 9. But it is somewhat more convenient, when the circumstances of the place will admit it to be so.

Make streets about 10 or 12 yards wide, parallel to the curtains, and bounded on one side by the rampart. About 15 yards distant from this street, within, draw another street about 9 yards wide. In the space *H* between these two streets, the barracks for lodging the officers and soldiers are built; and in the street next the rampart the piles of shot and bombs are sometimes placed.

The length of the plan of a barrack before a curtain is about 140 or 180 yards, and the plan of a pavilion *I* for the officers may be about 25 yards long by 16 or 18 yards broad.

Against those curtains where the public gates *E* are placed, the barracks are discontinued for about 40 yards on each side the gate, making an area about 80 yards long, and 36 broad, which serves for a lesser place of arms, where the guards of a gate-way draw up in case of a surprize: this area is also useful for the carriages that are going out to stop in, until those on the bridge coming in have entered the gate. In figures of 4, 5, or 6 sides this area is less.

The extremities *I* of the barracks next the gates and bastions are usually assigned for the officers pavilions, being the most airy places.

III. Of the rectangular plats made by the intersections of the streets, the most conveniently situated ones are to be chosen for the public buildings; such as the arsenal, church, town-house, market, house for the governor, and for the other chief officers in the service of the state; and on the remaining plats houses are built for the burghers.

Beside the guard-houses of the gates there should be others made on the ramparts for the centinels appointed for the night watch; these guard-chambers are often placed at the centers of the necks of bastions, when in those places there are no cavaliers or magazines of powder. They are also well disposed, when set on the middles of these curtains where there are no public gates, especially when there is a water-gate through which runs a canal or river.

The arsenal should be erected in a place the least liable to accidents of fire; and if there is a conveniency of water-carriage in the town, the arsenal should be placed as near the water as may be.

There are no general rules to be given for fixing the places on which the public buildings are to be erected, because the circumstances by which engineers regulate their plans are various. Therefore in the figure

referred to, which is a regular pentagon fortified in the common way, the streets and buildings are laid out in imitation of their disposition in *New Brisac*; which being in general esteem is usually proposed as a pattern for beginners.

There are many writers on this subject, who propose to make the great place of arms, or parade, similar to the figure of the town when regular; and from the angles and sides of this parade, draw streets to the middle of the bastions and curtains; but as this disposition spoils most of the corner houses in the town by making the walls at oblique angles to one another, it was thought sufficient barely to mention such constructions.

Of Bridges.

112. The passage over the moats of fortified places is by bridges, most commonly made of timber, and supported by frames rising from the bottom of the ditch: such bridges are either *private* or *public*.

PRIVATE BRIDGES serve for the easy communication between the town and the outworks.

PUBLIC BRIDGES are those by which carriages and passengers go over when they come into or depart from the town.

Bridges consist of two parts, namely, the *fixed* and *moveable*.

The FIXED or DORMANT parts of a bridge are those parts, which are strongly joined to the supporting piers; and are never moved but in the cases of repairs, or during a siege.

The MOVEABLE or DRAW-BRIDGE is a floor of timber framed together, one end of which serves as an axis, by which the other end may be drawn up or let down by some easy contrivance: the most common way is by a kind of balance called *plyers*.

The PLYERS are two timber levers about twice the length of the bridge they lift, and joined together by other timbers framed in the form of a St. Andrew's cross, which serves as a counterpoise. The plyers are supported by two upright jaumbs, on which they swing; and the draw-bridge is raised or let down by the means of chains joined at the ends of the plyers and bridge.

The breadth of a public bridge is usually about 16 feet, including the rails and footway of about 3 feet on each side: but the breadth of the draw-bridge is only 9 or 10 feet, and its length about 15 feet.

A draw-bridge is generally placed close to the gate, whether it be the gate of the town or that of an outwork; and is then by the means of the plyers drawn up against the gate. But when a bridge is more than 40 yards long, it is usual, beside the draw-bridge at the gate, to put another about the middle of the bridge.

113. *To draw a Bridge in the Plan of a Fortress.*

Before the gates draw four lines across the ditch, making three intervals or spaces, the middle one being 10 feet broad, and the space on each side three feet.

Divide the length of the bridge into parts of about 16 feet long each, to express the distance between pier and pier, or the bays of building; and against each division, on the outside of the lines, make a square of a foot, to express the ends of the piers supporting the bridge.

Allow the bay next the gate for a draw-bridge; and if the length of the bridge exceeds 40 yards, allow the middle bay for another draw-bridge. These are to be distinguished by drawing two diagonals across the middle interval of these bays, that of the other bays having lines drawn across them at a small distance from one another, and the space on each side left white for the footway; which is to be broken off at each draw-bridge. See figs. 13, 15. Plate XVI.

114.

Of the Orillon and Retired Flank.

When the besiegers of a fortress have made a breach in the face of a bastion sufficiently perfect, and have every thing ready for the storm, they cross the ditch to the attack, if the besieged will suffer it to be brought on. In this attack, the fire from the flanks is the most effectual defence; and cannon placed there, loaded with grape or case-shot, would do great execution. But of this the besiegers are well aware, and therefore take care before-hand to dismount all the cannon flanking their intended passage of the foss; and as this cannot be well prevented by the besieged, especially when the flanks are plain ones, several of the most eminent engineers have proposed, and actually built part of the flanks retired behind the ordinary limits, leaving at the shoulder of the bastion a mass of earth, commonly called an Orillon, which is to serve as a screen between the enemy's direct fire and a part of the flank. In this covered part is reserved one or two cannon, to be used only in the defence of the breach in the face of the next bastion.

This notion of covering part of the flank is almost as old as the modern method of fortification.

115. *To construct the Orillon and Retired Flank.* Plate XVI. Fig. 10.

1st. At right angles to the face As , draw from the angle of the shoulder the line sb equal to 8 or 9 yards, and make b the center of the arc sa , forming the *orillon*.

2d. From a point z , in the face of the next bastion, fig. 6, about 15 yards from the point A , draw through a a line zm ; in which, and also in the line of defence Ar produced, take the *brisures* or *breaks* am and rn , each 10 yards.

3d. From m and n , with the radius mn , describe arcs cutting in d , which make the center of the arc mn , or *concave flank*.

4th. In dm produced, which serves as the termination at this end, lay the several breadths of the parts of the rampart; as the parapet=6 yards, foot-bank=2 yards, walk=12 yards, and the slope=4 yards; then from the center d , through those points, describe arcs, meeting the parapet, foot-bank, and rampart lines of the *brisure*, these being in the continuation of the like lines drawn within the face of the next bastion.

The

The parapet of the orillon is drawn parallel to *s a* at 6 yards distance.

The axis or middle line of each uncovered embrasure in the flank, should tend toward a point about the middle of the foss opposite the flanked angle of the next bastion.

The wall in the upper brisure *a m*, as it cannot be battered, need not be above 2 or 3 feet thick to support the earth behind it.

Through this wall there should be a sally-port coming out at the bottom of the foss if a dry one, or a little above the water line in a wet foss. The descent to this port is by a passage under the rampart of the flank; but in straight flanks the sally-port is in the curtain next the angle of the flank, the passage to it being under the rampart of the curtain.

The entrance into these sally-ports is marked on the inner slope of the rampart against the letters *v*.

116.

Of Double Flanks.

The progress of the works of the besiegers generally depends on their having a greater army than is in the town besieged, and of forming a greater fire on the town than it can return; therefore some engineers have endeavoured to hinder the progress of the besiegers batteries, by furnishing the town with an equal, or rather a superior fire; and this has been proposed to be effected by making second and third flanks, one behind another, gradually more elevated than those before. For as it is found convenient to silence the fire of the flanks, before the besiegers can avail themselves of the breach they make in the face of the bastion; batteries are made against the flanks, and kept playing at the same time with those against the faces. Now the batteries for the ruin of the flanks can be conveniently made only within 10 or 12 yards of the head of the glacis, and their length not greater than about 40 yards, containing at most about 6 or 7 cannon. But if the besieged can by any artifice preserve the cannon in the opposite flank, and have a greater number there than are in the battery opposed, their fire will of course be superior, and ruin the battery intended to offend them; and this was expected to be accomplished by *double*, or *cazemated flanks*.

In some places two or three tier of cannon were placed one above the other, the upper ones being supported by vaulted work, as in the Tower of London; but such having been found very inconvenient, on account of the great smother contained in the vaults, they have been generally constructed open.

The cazemated flanks have been condemned by many writers, because they may be rendered useless by the enemy's bombs; were this objection just, it would hold against any small work; for the besiegers having once got the length to any place, may render that place also useless to the besieged; and it would thence follow, that it were best not to have any places of defence. But as the utility of such works has been commended by some of the most eminent engineers, it was judged proper to mention here how these flanks may be constructed.

SECTION V.

117. *Of Works for the Defence of the Foss.*

Such works are usually called *tenails*, or *ramshorns*, or *caponiers*.

A **TENAIL** is a work raised in the ditch before the curtain upon the lines of defence.

A **RAMSHORN** is a curved tenail raised in the foss before the flanks, and presenting its convexity to the covered-way.

A **CAPONIER** is a kind of covered-way or gallery across a dry ditch before the middle of the curtain; and limited between the lines of defence and the counterscarp.

The *tenails* never rise above the common ground level, but are frequently two or three feet lower: they consist of a rampart of about 12 or 15 yards thick, covered by a parapet of cannon proof, with one or two foot-banks. These works are placed at such a distance from the curtains and flanks, that the splinters of stone knocked off them by the besiegers cannon may not hurt the troops posted there to flank the enemy in their passage of the foss; which is the principal use they are made for.

The *caponier* is of like use, but is usually sunk about two or three feet lower than the bottom of the foss. It is about two or three yards broad, and is covered by a parapet about 6 feet high on each side, which slopes away like a glacis about 15 yards broad. It is frequently covered by a roof made with hurdles, to sustain a floor of earth about a foot thick, and the whole supported with thick planks musket-proof, with convenient loop-holes for the defendants to fire through.

118. *To construct Tenails. Plate XVI.*

First fort with flanks, Fig. 11. Parallel to the curtains and flanks, draw the lines eg at 4 or 5 yards distance, and Ee, Gg , at 10 yards distance: from F , and D , the middles of CG, CE , draw the flanks Ff, Dd , at right angles to the lines of defence Ag, Be ; draw the curtain df , and put in the rampart, parapet, and foot-bank.

Second fort with faces only, Fig. 12. Take the distances from the curtain and flanks, the same as before; and to the lines of defence annex the rampart and parapet.

Third fort with faces and curtain, Fig. 3. When the lines of defence cross one another in D , so near the curtain that there is not room for the thickness of the rampart and its distance from the curtain, make the face ab, cd , each of $\frac{2}{3}$ of AD , and draw the curtain db .

119. *To construct a Caponier. Fig. 12.*

From the exterior flanking angle D draw a line Dp to the angle of the counterscarp p ; on each side of Dp draw parallel lines, at the distances of $1\frac{1}{2}$, $2\frac{1}{2}$, and 15 yards from Dp ; these lines being limited by the lines of defence and counterscarp, form the caponier.

This work, which can be used only in a dry ditch, serves, besides its defence of the foss, for a convenient passage between the town and its outworks; and in this case there is usually a circular excavation made in the

the angle of the counterscarp, out of which the troops may defile without being seen by the enemy.

120. *To construct a Ramshorn.* Plate XVI. Fig. 13.

A line Da drawn from D , the angle of the shoulder, at right angles to the line of defence, its intersection a with BI , the other line of defence continued, gives the center a ; from which, with the radius aD , describe the outline AC of the ramshorn, CD being equal to 15 yards; and annex a parapet, foot-bank, and walk, as in the other tenails.

This work seems preferable to either of the other tenails, both on account of its simplicity, and the defence for which it is constructed.

SECTION VI.

Of Outworks.

121. OUTWORKS are all those works advanced beyond the foss, serving to augment the defence of the town, to cover the gates, bridges, and other weak parts; to enclose those eminences, not too far distant, which command the town; to surround and defend the suburbs, if any; and, in fine, to throw so many difficulties in the way of the besiegers, that, by the length of the siege, the enemy may waste both his time and troops; besides, such protraction frequently affords an opportunity of obliging him to raise the siege, either by the approach of a relieving army, or by the setting in of a season unfit for military business.

The outworks recorded by engineers are various, such as *ravelins*, *half-moons*, *lunettes*, *counterguards*, *horn works*, *crown works*, *tenails*, and several others. But many of them having been found defective, are now disused in all new works and alterations; and therefore those only which are now in most esteem will be here treated of, referring the more inquisitive readers to the writings of *Mallet*, *Dedier*, *Le Blond*, *Muller*, and others.

122. The constructions of outworks depend on much the same principles as those of the place itself; to which may be added,

1st. Every part of an outwork ought to be flanked or defended either from some neighbouring work, or from the town itself; that the enemy may not find any place of real shelter among the outworks, without being at the labour of throwing up a covering for himself.

2d. As the chief defence depends on the musket, the parts mutually flanking one another ought to be within the ordinary reach of that weapon; that is, not exceeding about 300 yards.

3d. Every outwork ought to be commanded from the town; and therefore the more advanced works are ever to be the lowest. The gradation usually observed from work to work is about three feet; that is, the rampart of all works advanced before a place gradually diminish three feet in height from the rampart of that place; thus if the town ramparts are 18 feet high, the rampart of the next outwork is 15 feet high, that of the work next advanced is 12 feet, and so on; thus the more advanced outworks are commanded by those next within.

4th. The flanked angle of an outwork ought not to be less than 60 degrees.

5th. Each outwork should be surrounded with a ditch communicating with the foss of the town. When all the ditches can be filled with water, they ought to be equally deep; but when that cannot be obtained, the ditches of outworks should be shallower than that of the town; by which means the front of the outworks will be better defended from the parts which flank them. These ditches are usually from about 20 to 24 yards broad, and rounded to that breadth before the salient angles, with the counterscarps parallel to the faces or outlines of the work they encompass.

6th. The parapets of outworks are to be equally strong and high with those of the town, as they are to be cannon proof, and to cover the troops posted on the ramparts of those works. So that it is usual to make the parapets of outworks of about 18 feet thick, 6 or $6\frac{1}{2}$ feet high, with a foot-bank $4\frac{1}{2}$ feet lower than the crown or crest of the parapet; and the walk of the rampart about seven or eight yards broad, with a slope within of about once and a half its height.

When the plan of a fortification is to be drawn, in which are outworks, the counterscarp of the great foss is to remain in black-lead pencil, until the outworks are annexed in pencil also, with their fosses; then the covered way and glacis are to be drawn surrounding the fosses of all the works.

123. *Of the Ravelin.* Plate XVI. Figs. 14, 15, 16, 17.

A RAVELIN is a work made before a curtain, serving to cover it and the adjoining flanks from the direct fire of an enemy. It is composed of two faces, AB, AC (fig. 14), and the two demigorges pB , pC , taken on the counterscarp.

To construct a ravelin. In a line drawn at right angles to the curtain through its middle, take the capital pA equal to about 100 yards, and draw the faces AB, AC, directed to points in the faces of the next bastions, about 10 yards distance from M, the angle of the shoulder.

In this work put a rampart of about 16 or 20 yards, and a parapet of about 6 yards; and before the faces put a foss of about 24 yards wide, rounded before the salient angle A; also annex ramps in the slope of the rampart, and, if proper, construct a barbet in the salient angle.

The gorge of the ravelin, or the part next the town, is left open, without any rampart; because the enemy cannot attack it there; and also, that it may be entirely commanded from the ramparts of the town.

R E M A R K S.

124. It is proper to make a ravelin before every curtain, as the flanks are by these means covered from the enemy, and cannot well be ruined before he is master of the ravelin; without which, he would have it in his power to batter the flanks from the counterscarp, both from before the curtain and the face of the bastion; the latter of these being the only place he can do it from, when a ravelin is interposed, of which he is not master.

master. But the difficulty of erecting a battery on the head of the glacis against the face of a bastion, is rather too great to be undertaken, while the place is defended by the whole fire of the adjacent face of the ravelin; and therefore the besiegers can scarcely hurt the flanks before they have taken the ravelin; consequently such works greatly augment the defence of a town.

125. As the face and foss of a ravelin is defended by part of the face of the opposite bastion; therefore the faces of the ravelin should be directed somewhat within the angle of the shoulder, at least as much as the breadth of the parapet and foot-bank of the flank; besides, by this construction they cover the flanks more effectually, which is one of the principal things wanted, as the flanks are of most importance, and to be preserved the longest.

126. In wet ditches, where the troops pass from the town to the ravelin in boats, it is proper to make a kind of harbour in the gorge of the ravelin, where the boats may lie covered from the fire of the enemy; and this may be done various ways: One is, by making an excavation limited by an arc described from A (fig. 15), the angle of the counterscarp, with a radius of about 20 yards. In dry fosses, it is proper to have either ramps or stairs in the gorge of the ravelin, to preserve a free communication, should the bridges be broken by the enemy's shot.

127. In some ravelins, (fig. 16) there is constructed a kind of *redoubt*, or *KEEP*, which is a small work similar to the ravelin, with a ditch of about 10 or 12 yards wide. The capital may be about 30 or 40 yards; and the work covered in the faces by a wall of a foot or two thick, furnished with loop-holes for the musketry to fire through.

This *keep* serves to secure a retreat for the troops who defend the ravelin, and on this account the defence of the breach in the ravelin may be more obstinately maintained; and even when the defendants are obliged to give way to a superior force, they may retire into the *keep*, and prevent the enemy from making a lodgment in the outward part of the ravelin, or at least greatly obstruct it; and cannot be driven from this place until the enemy has erected a battery, and brought cannon on the ravelin to batter the *keep*.

The construction may be otherwise made by taking the distance BA equal to about 20 yards on the gorge of the ravelin, and out of the rest forming the *keep* with its foss; the scarp and counterscarp being drawn parallel to the faces of the ravelin, the two fronts of which form a work covering the *keep*, and is usually called the *counterguard*.

128. The ravelins, called by some authors *half-moons*, have sometimes their corners at B and C, fig. 14, cut off, either parallel to the capital p A, or at right angles to the foss, making a kind of flank about 12 yards long, with its rampart and parapet. This serves to give a more direct fire along the covered-way, which is meant more particularly to be defending; but then it partly lays open the flanks, which the ravelins were originally intended to cover.

129. The celebrated General *Coehorn*, in the ravelins which he built at *Bergen-op-Zoom*, contrived a very good defence for the covered-way before the faces of the bastions, by making retired flanks in the breasts of the ravelin, where one or two cannon might be placed as secure from the

the enemy's fire, as those behind the orillon of a bastion. These covered cannon in the ravelin seem to have been intended for the defence of the covered-way on the last emergency, as those in the bastion were for the defence of the breach, when the besiegers brought on the storm. But the covered cannon in the ravelin seem to have this preference; that as towns are not usually given up until the enemy is master of the covered-way, the secreted guns in the ravelin have an opportunity of being employed in the use for which they were placed there; whereas the guns covered by the orillons are very rarely of any use, as there are few garri-fons which stand the storm of the breach in a bastion.

130. *Coehorn's* ravelins may be imitated by the following construction. In the gorge of the ravelin take ab , fig. 17, equal to about 20 yards, draw the flank bc at right angles to ab , make bc equal to about 12 or 14 yards, and draw the cover cd parallel to ab . To the flank bc annex a rampart, parapet, embrasures, and ramp; and to prevent these flanks being raked from the enemy's batteries, particularly by the *ricochet*, or bounding shot, there may be made a traverse about 10 feet thick across the top of the flank at c , with a small mine under it, to blow up the traverse when the besieged are obliged to quit the ravelin, lest it should serve to cover the assailants from the fire of the town.

Coehorn has also made flanks at the corners d of the ravelin, which may be constructed by taking an equal to 10 yards, and drawing ne parallel to bc , meeting cd in d ; then de is the flank required.

It seems proper, when such ravelins are used, that the faces should spread on those of the adjoining bastions 10 or 12 yards farther from the angle of the shoulder, than in ravelins which have no flanks; and this is done at *Bergen-op-Zoom*, where the faces of the ravelins would fall between 20 and 30 yards from the angle of the shoulder on the faces of the bastions.

131.

Of the Counterguard.

A COUNTERGUARD is a work generally serving to cover a bastion: it is composed of two faces, forming a salient angle before the flanked angle of a bastion.

To construct it. Plate XVI. Fig. 18.

Having described the ravelins, and drawn their fosses, in the counterscarp of the ravelin, take ab equal to about 24 yards, and draw the face bc parallel to the counterscarp of the foss before the bastion; and the outline of the counterguard will be determined; the inner boundary being the counterscarp of the grand foss.

In this work put a rampart about 16 or 18 yards broad, with a parapet of six yards, and annex the ramps and a barbet if necessary: Also make a foss of 24 yards in breadth, the counterscarp being parallel to the faces.

The counterguard seems to be, next to the ravelin, one of the most useful outworks; for it occupies but little ground, is of no great expence, covers the faces of the bastion so effectually, that they cannot be battered in breach, until the enemy has made himself master of this work; and

and when he has it, he will meet with difficulties enough in finding earth to cover himself and erect his batteries; and must therefore be at a considerable trouble in bringing it from beyond the fofs, while he is exposed to the fire of the faces of the neighbouring ravelins; which, with the flanks of the bastions, are the defences of the counterguard.

132. *Of the Tenaillon.*

A TENAILLON is a work composed of a ravelin and two detached works called *lunettes*, which partly or wholly cover the faces of the ravelin from an enemy's direct fire.

When the detached works cover only the lower part of the faces of the ravelin, they are called *small lunettes*: but when they cover the whole faces, they are called *great lunettes*, and this is the work which is here meant by the word *tenaillon*.

133. *To construct a Tenaillon.* Plate XVI. Fig. 19.

Having described the ravelin and its fofs, the counterscarp of which is rt ; in the face ef continued, take tv equal to about 60 yards, and on the counterscarp of the grand fofs take rs equal to 25 or 50 yards; then drawing sv , the figure $rstv$ is the *great lunette*; to which a rampart, parapet, and ramps are to be annexed against its faces tv , and branches vs , of the same kind with those in the ravelin.

134. A great lunette may be considerably strengthened by making across its middle, at A, a retrenchment, consisting of a rampart, parapet, and a fofs about six or eight yards broad; and seven or eight feet deep; the parapet being drawn at right angles to the counterscarp of the ravelin against the middle of its face; and the ditch of the retrenchment communicating with that of the ravelin.

A *tenaillon* is a work capable of affording great defence to the besiegers, as was evident at the siege of *Lisle* in 1708, where the besiegers were twice or thrice driven out of a *tenaillon* they had taken and retaken.

135. *Of a Horn-work.*

A HORN-WORK is a fortification composed of two long sides, called branches, tending toward the town, and of a front formed by a curtain between two half-bastions.

This work, when used, is sometimes put before a bastion, but oftener against a curtain.

136. *To construct a Horn-work before a Curtain.* Plate XVI. Fig. 20.

In a line drawn from o , the angle of the counterscarp, at right angles to the curtain, take oc equal to about 250 or 260 yards; through c draw aa at right angles to oc , and make ca , ca , each equal to half oc , so aa is equal to oc .

Take

Take the *normal* CD equal to $\frac{1}{2}$ of AA, through D draw the lines of defence AI; make the faces AB equal to $\frac{1}{2}$ AD; transfer the distance BB from B to I the line of defence, draw the flanks BI and curtain II, and draw the branches AQ toward some point in the face of the bastion, about 8 or 10 yards from the angle of the shoulder.

Against the faces, flanks, curtain, and branches, put a rampart and parapet as in the ravelins; make a foss of 24 yards in breadth before the flanked angles A, the counterscarp of the foss in the front being directed toward B, the angle of the shoulder, and the rest drawn parallel to the branches.

A small ravelin is usually put before the curtain of a horn-work, for the same uses as that before the curtain of the town. Make the capital CP about 60 yards, draw the faces as in the large ravelins, and make a foss about 15 or 16 yards wide, the counterscarp of which is parallel to the faces of the ravelin, which are to be furnished with a rampart and parapet.

137. Retrenchments are sometimes made in the horn-work, as in the great lunette, and for the same reason, namely, to increase the difficulties of an enemy in a siege.

Also a ravelin with its foss is made before the curtain of the town, independent of the horn-work, which it commands.

138. There is another work, called a Crown-work, the front of which consists of a whole bastion, two half-bastions, and two curtains, and is bounded on the sides by two long branches directed toward the town. This work is like two horn-works connected together, by their branches being put side to side.

Horn-works and *Crown-works* have been chiefly used to inclose some rising or hollow ground, or a suburb; but are now in general disesteem, on account that their defence is very small in proportion to their cost, a circumstance by which all works should be partly rated.

There are several other works called out-works, which may be found in the treatises written on Fortification, but are here omitted on account of the intended brevity of this work.

139.

Of the Covered-way and Glacis.

When all the intended outworks are annexed to the plan, and the several fosses are drawn, communicating one with another, the covered-way and glacis are to be drawn parallel to the counterscarps of the fosses; and a foot-bank is to range quite round the covered-way, at the foot of its parapet. The top of this foot-bank should be at least four feet broad, that there may be convenient room left for the troops to stand on, after the pallisades are planted, a row of them being always to run quite round the covered-way. The manner of setting them, as recommended by the most celebrated engineers, and particularly by the great marshal *Vauban*, one of the most experienced men in military works that ever lived, is to put the pallisades on the upper foot-bank about a foot distant from the foot of the parapet, sunk in the ground at least three feet, and their top on a level with the head or crest of the glacis.

Pallisades

Pallisades thus placed are not exposed to the cannon of the besiegers; the most they can do will be only to brush their points; neither can they be easily jumped over by the troops commanded to the attack of the covered-way, nor readily cut down; and their distance from the parapet leaves a space sufficient for men to go along to repair any disorder.

140.

Of Places of Arms.

PLACES OF ARMS in the covered-way are spaces made at the entering and salient angles, considerably larger than the street of the covered-way, and formed by turning the head of the glacis into two faces projecting toward the country; those at the salient angles are formed by the roundings of the counterscarp; but those at the entering angles are thus constructed. Plate XVI. fig. 3.

In the head of the glacis take the gorges co, co , from 20 to 30 yards; draw the faces ot, ot , so that the angles to a be between 90 and 100 degrees; and parallel to those faces draw a glacis of about 50 yards.

The faces ot of the *entering places of arms* should not make angles greater than 100 degrees with the *branches of the covered-way* oa , because those branches could not then be defended so well by the musketry, as when their shot was delivered directly along the glacis, nearly parallel to the branches, which can only be done when the defences are nearly at right angles to the places defended.

Some writers have advised to round all the salient angles of the places of arms, because those angles could then be defended by more men: perhaps there might be some advantage in notching the faces somewhat like a redan, as mentioned at Article 69.

141. The great *Coehorn* was so conscious of the advantage of places of arms at the entering angles for the defence of the covered-way, that he was very particular in their description, and took such care in the construction of those at *Bergen-op-Zoom*, that they very well answered his design, as was evident in the famous siege of this place in the year 1747.

Coehorn's Places of Arms may be thus imitated.

Plate XVI. fig. 21. where the work is on a larger scale, to be plainer.

Take the gorges ab, ab , about 45 yards, and the faces bc, bc , about 50 or 60 yards. At 10 yards distance from the faces, draw the *first lunette* A , with a ditch before its faces, both together being about ten or twelve yards broad, its ends being terminated by the line ab . Within this, at about 10 yards distance, draw a second lunette B of about five yards broad, its ends stretching about half-way the breadth of the covered-way. Behind the ends of each lunette, at the distance of two or three yards, put a traverse of about five yards thick, reaching from the counterscarp about two or three yards farther than the ends of the lunette. And about the angle of the counterscarp make a skreen of about six yards in each face and gorge; which skreen is to be of brick-work with loop-holes for the musketry, to favour the retreat to the defendants when driven from their works in this well-contrived place of arms.

142. *Of*

142.

Of Traverses in the Covered-way.

When the besiegers have pushed on their approaches so far, as to be within 30 or 40 yards of the head of the glacis, it will be in their power to rake the covered-way from some of their batteries; to prevent which, and also to shelter the troops in some measure from the ricochet or rebounding shot, traverses are thrown across the covered-way, particularly on each side of every place of arms, and in every branch of the covered-way where the length of that branch exceeds 50 or 60 yards.

Each traverse is furnished with a foot-bank; and a row of pallisades planted on the foot-bank; and the passage round its end should be furnished with klinkets or doors, to shut it up when necessary.

143.

Of Sally-ways.

In the middle of some faces of the entering places of arms a sally-way is made, which is a passage cut through the parapet, or head of the glacis, to facilitate the sallies of the besieged. To make sally-ways in the places of arms salient would be improper; because as those places are the most convenient to be first attacked, they should not by any means be weakened.

These passages are cut oblique to the faces of the places of arms, and wind toward the salient angle in such a manner, as not to be easily enfiladed or raked; they rise gradually from the foot of the parapet, until they meet the slope of the glacis, at the distance of seven or eight yards from its head. The roads to the town commonly pass through these sally-ways; every one of which would be furnished with a good barrier, to shut up against surprizes and sudden attacks.

144.

Of Communication.

Every detached work in a fortification should have a ready and free communication preserved, otherwise they might be disadvantageous to the place.

Communications are preserved in various other ways than by bridges, which are liable to be destroyed by the enemy's cannon. In dry fosses it is thus:

From the town to the tenail, by a subterraneous way under the rampart in the middle of the curtain into the foss, and rising thence by ramps or stairs into the tenail: from the tenail by a subterraneous way into the caponier, and thence to the ravelin, either by ramps, stairs, or a timber stage: from the ravelin to the works beyond, the communication is kept in like manner; or sometimes a way is sunk across a ditch, and covered with a parapet next the enemy; and the way from the foss to the places of arms is also by stairs, or by a timber stage.

Over wet ditches the troops are conveyed by boats, or rafts, or by little bridges about three feet wide lying nearly level with the water's edge; but the latter are inconvenient in the night, and much more so when the defendants are obliged to quit the work precipitately.

In the gorges of ravelins and other outworks, a space or passage five or six feet wide is left between the counterscarp and the end of the rampart, which serves for the communication between that work and the covered-way.

When

When wet fosses are to be represented in plans, it is done by giving them a tint with distilled verdigrise along the borders of their scarps and counterscarps; but in printed plans it is expressed as in the ditch of the ravelin at fig. 15; and dry ditches are shewn in coloured plans by washing the said borders with a tint of brown bistre; but in prints dry fosses are expressed as in the ditch of the ravelin at fig. 14: And a cuvet is represented by a double line drawn along the middle of the foss, as against the front BB of the polygon.

145.

Of Works beyond the Glacis.

Sometimes, when earth is wanting to raise the several works to their proper height, or when the defence is to be increased, a foss about 20 or 25 yards broad is sunk at the foot of the glacis, encompassing either the whole or some convenient part of it. But then it is proper that the glacis should slope quite to the bottom of this foss, if it is a dry one, or a wet one which can be drained; for otherwise, when the enemy comes to be possessed of it, he would find a trench ready dug to screen him from the fire of the covered-way, and other places.

To this advanced foss is usually annexed, when it can be, a covered-way and glacis; and there are not wanting fortifications, which have three covered-ways and glacises one before the other.

146. Before some of the salient angles of the glacis there are sometimes constructed a kind of work, called a *lunette*, or by some an *arrow*. It consists only of a parapet and foot-bank forming two faces, making a salient angle, the legs of which are parallel to the head of the glacis, through the ridge of which runs a narrow passage to the lunette.

147. Sometimes works called *redoubts* are constructed before the salient angles; some of these works have fosses, covered-way, and glacis; others are made to depend on their own defence; but to all these detached works a proper communication must be preserved with the covered-way, and in such a manner as not easily to be cut off. When this passage is two or three times as long as the glacis is broad, the passage should have one or more traverses across it, to prevent its being raked; also, on either side, it should be covered by a parapet and small glacis.

148.

Of Profiles.

The **PROFILE** of a work is a figure expressing the several heights, depths, and breadths of that work.

The profiles of works are regulated according to their use, and also according to the quality of the materials with which those works are to be made.

Thus the ramparts of the town are ever thicker than those of out-works; the breadth of the parapet only remains nearly the same in most works: besides, a rampart made of good firm earth need not be so thick as one made of loose and sandy materials; from 20 to 24 yards will do in the former case; but less than 25 or 30 yards will not suffice with poor earth.

Profiles

Profiles are also regulated with regard to the expence intended to be bestowed on the works ; that is, according to the outside coating or walling of the rampart and parapet, namely, whether it be done with earth or intire masonry, or half one and half the other.

149. When a work of earth is raised, and the surface is covered or plaistered with a tenacious substance made of well-tempered earth or loam, this coating or plaistering is called *placcage* or *crusting*.

And when the surface is covered with grass turf, or, as it is most common, with clods of fat mould cut in the form of wedges, and called *gazons* or *fods*, this kind of coating is called *gazonage* or *jodding*.

150. When the whole front of a work, from the bottom of the foss to the crown of the parapet, is covered or fronted with a wall of stone or brick, this kind of work is called *entire masonry*.

151. When the front of the rampart, from the bottom of the foss to the horizontal line, or ground level, or a little higher, is fronted with a wall of brick or stone, and the remaining part of the front is coated with earth, the work is called *half masonry*.

Construction of Profiles.

152. When the works are coated with earth. Plate XVI. fig. 22.

Let *AHLQ* represent the horizontal, or ground line, taken through the face of a bastion, and across the foss, and through the covered-way and glacis : in this line take the following measures ; namely,

$AR = 3$ or 4 yards ; $Rc = 10$ yards : $cd = 6$ feet ; $de = 1\frac{1}{2}$ feet ; $eg = 18$ or 20 feet : $ga = 12$ or 14 feet ; $ah = 9$ feet ; $hl = 12$ feet ; lm = breadth of the foss ; $ml = 12$ feet ; $LM = 5$ yards ; $mp = 7\frac{1}{2}$ feet ; $pQ = 50$ yards.

Through the points *R, c, d, e, g, l, m, M, p*, draw lines perpendicular to *AQ*.

In these lines take $RB = 3$ or 4 yards ; $cC = RB + 2$ feet ; $dE = cC + 1\frac{1}{2}$ feet ; $eF = dE + 4\frac{1}{2}$ feet ; $gG = cF - 2\frac{1}{2}$ feet ; $li = 18$ feet ; $mk = 18$ feet ; $mo = 2$ feet ; $pP = 8$ feet.

Draw the lines *AR, BC, EF, FG, Ga, HI, KL, Lo, PQ*. Then draw *ED* parallel to *AH*, and equal to 3 feet, and draw *DC* ; also dispose of the space between *o* and *P*, in like manner as between *c* and *F*.

Then will the several parts of the profile be completed, and represented ; namely, *BA* the inner, and *Ga* the outside, slopes of the rampart, to which *BC* is the walk ; *FE* the inside, and *FG* the crown of the parapet ; *CD* the slope, and *DE* the top of the foot-bank ; *aH* the berm or foreland ; *HI* the scarp ; *KL* the counterscarp, and *IK* the bottom of the ditch ; *LM* the covered-way ; *oN* the slope, and *NO* the top, of the foot-bank ; *OP* the inside of the parapet, and *PQ* the slope of the glacis.

The pallisades *k* are put on the top *NO* of the foot-bank.

153. In ramparts coated with earth it is usual to set a row of pallisades in the front of the rampart, as at *b*, about five or six feet below the crown of the parapet. These are not planted upright, but nearly horizontal, the point dripping a little below the level ; and this work, which is called *fraising* or *staccage*, is done to prevent surprizes by scaling, and also to hinder desertions.

154. In

154. In most ramparts coated with earth, whether of the town or out-works, it is usual to plant on the berm, either a row of upright pallisades, as at *f*, or a quick-set hedge of thorn, which should be kept constantly cut, to make it grow thick: either of these methods serves to cover the troops in going their rounds. Sometimes both pallisades and hedge are used, the hedge standing foremost.

The salient angles of all earth-works should be rounded off; otherwise the weather would soon destroy the angular edges, and make them look worse than the other parts.

155. *When the coating of the work is entire masonry. Fig. 23.*

Having determined all the parts through the rampart to the line *Gg*, as at Art. 152; in *Gg* take $GI = 3$ or 4 feet, for the upright face of the parapet; on *I*, with the radius of one foot, describe a semicircle representing the *cordon*, which is a large semicircular moulding that ranges along the whole front; take *gr* equal to 18 feet, and draw *rcst* parallel to the ground line, and this represents the bottom of the foss. Take *rc* and its parallel *ia*, each equal to 5 feet; draw the scarp *ic*, and draw *ab* parallel to *Gg*, which continue to about 6 feet below *rc*, and this line represents the back of the wall; through *b* draw a line *bdmn* parallel to the ground line, and this represents the bottom line of the foundations, which is usually about 6 feet below the bottoms of the fosses; though in some cases it must be more; and let the foundation line *bd* project about 2 feet before the scarp line *ic*. Draw a line about 3 feet behind the front line of the parapet *GI*, parallel to it, which will represent the thickness of the front wall of the parapet; to which must be annexed, at *G*, a little projection, of about 6 inches in sally and height, to express the coving stone; and the outlines of the profile of the rampart will be completed.

156. From the directions already given, it will be easy to conceive how to regulate the profiles of out-works, whether they are to be fronted with turf or masonry; and according to Art. 155, where the other profiles of the masonry annexed in the figures 24 and 25; that of 24 being a tenail before the curtain, of which no more than the parapet rises above the ground level; and consequently the walls to support this work need not be so thick as those are, which sustain the lateral thrust of higher banks; and for the same reason, the counterscarp walls are of a less strength. In the ravelin, fig. 25, the front is half masonry, or the walling is carried up to the ground level, and the front of the rampart and parapet is supposed to be coated with earth; but the walling in this case should project about 2 or 3 feet below the foot of the rampart, in order to preserve a proper berm.

157. The walks of all ramparts, and also the covered-way, should slope backward, in order to carry off the rain; this sloping may be about half an inch, or an inch in a foot.

158. The scarping usually given to earth facings is about 8 inches on 12, or the base of the slope is $\frac{2}{3}$ of the height; and the scarpings generally allowed to fronts of masonry is about $\frac{1}{3}$ or $\frac{1}{6}$ of its height; and with regard to the thickness of the walls, Mr. *Vauban* usually allowed about 5 feet at top, and gradually thickened toward the bottom by their

scarping of 1 foot in 5 of height; and this profile he has experimented in the works of 150 towns, where he has directed the building of more than 4000000 of cubic yards of walling. But in order to add a greater strength to his walls he places buttresses, built of rough stone, at distances of 18 feet from one another on the inside. These buttresses are in length about the thickness of the wall at the bottom, and their breadth on a mean, about half their length; and they are carried up as high as the cordon, which greatly contributed to take off the thrust of the bank against the wall.

159. At the flanked angles of bastions, and other works, the parapet should rise about a foot or two higher for about 12 or 14 yards on either side the angle, than along the rest of the faces, and the same should be observed for about 4 or 5 yards on each side of the more exposed salient angles of the covered-way: for by these means, the troops ranged along those faces will be somewhat better defended from the ricochet, or bounding shot.

160.

Of Irregular Fortifications.

When a town or other place is to be fortified, it generally happens that the polygon which best circumscribes its plan will be very irregular, and consequently the fortifying of that polygon will not fall under the rules already given for regular fortification: it is therefore proper to point out to a learner how he may proceed on such occasions.

161. Let the plan of the place be circumscribed, if possible, by a polygon, the angles of which are all salient, none less than 60 degrees, nor much greater than 120; and none of the sides less than 200 yards, nor greater than 350. This polygon, which is to be the interior one, should have its sides not less distant from the houses than 50 yards; and the fortification is to be made from the interior side.

Through every angle of the polygon draw a line bisecting it; and on these lines, continued without the polygon, lay from the angular points the capitals, (in the Table, Art. 86) of those polygons, the angles of which are nearest to the angles in the given irregular polygon. Also on each side of the capital, from the said angles, lay the demigorges, corresponding to the capitals used on the sides of the polygon.

Then the lines of defence being drawn, and the corresponding faces laid on them, the *master-line* of the fortification to the given irregular polygon may be readily completed (as in Art. 91); to which the rampart, foss, and proper out-works, may be annexed, as before shewn.

162. In circumscribing the given place with a polygon proper to it, if it should so happen, that the sides, when drawn at the distance of 50 yards from the houses, make a polygon very different from that above directed; then must the positions and lengths of all those lines, or of some of them, be changed, and various ways tried, when the situation will admit of those various trials, until one is hit upon which will suit the place and come near the foresaid limits, which may be done by enclosing a larger space, and permitting the sides of the polygon to run farther from the houses in some places than 50 yards. And although by these means the fortification will be more extended, and thereby occasion a greater expence both in building and defending; yet as by its nearer approach to regularity, it will be stronger in itself, and more effectually answer the end

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of fortifying, the latter considerations may, on some accounts, be preferred to the former.

163. It should be observed, that regularity is not confined strictly to such polygons only as can be circumscribed by a circle, or nearly so; for a polygon inscribed in an oval kind of figure will have a great regularity, and may be made almost equally strong, by putting the stronger kind of out-works at the narrow ends. For as these ends, on account of their small breadth in proportion to the longer sides, cannot flank the approaches of an enemy so well as the longer sides, and as the enemy is not under a necessity of extending his works so much; consequently the smaller ends may be more advantageously attacked, and therefore should have their out-works stronger.

164. If the situation is such, that one or more of the sides of the circumscribing polygon cannot by any easy means be made less than 400 yards or more; then such sides should be divided into parts of some number of yards, between 200 and 350, as many as its length will admit of, which may then be considered as composed of so many polygonal sides. At every division, make such a bastion as the limits will admit, taking care that the faces of each are commanded by the adjacent flanks of the next bastions.

165. When any of the angles become too acute to make in that place a whole bastion, the angle may be diminished only on one side, making there a half bastion, and let the other side be either left as one line, or make two or three small flanks in it, in the nature of a redan (71); observing that the whole front is commanded by the flank of the next bastion. Or should the angle be too small even for a half-bastion, then both sides may be fortified in the manner of redans, and commanded from the flanks of the next bastions; but, in the case of these acute angles, the angular point should be made very solid, and the sides about such angle shorter than the others.

166. Should the polygon have one or more entering angles, which cannot be avoided; when that angle is near 90 degrees, and the adjacent sides do not each exceed 250 yards, those sides, with the assistance of the flanks of the next bastions, will very well defend one another, and also the entering angle: but should the angle exceed 120 degrees, then put against that angle a work like a bastion, if it can be; or if there is not room for the projection of the flanked angle, make but one face, observing that it be raked from one of the adjacent flanks.

167. A town that has been fortified in the ancient manner, and has already a good rampart and foss, may be put into a good state of defence against the modern methods of attack, by adding outworks so disposed as to cover the town wall, be mutually defended by one another, and commanded from the ramparts of the town. Such a place, with the outworks judiciously disposed, may hold out as many days as a place formed on a regular plan, which has been evinced from the good defence made by several towns fortified in this manner.

168. There is a multitude of other things that might be said on the business of irregular fortification, which, on account of the designed brevity of this tract, must be omitted; but after all, the best notions are acquired in these matters from studying the plans of the fortified towns in several parts of the world. Collections of these plans may be met with at most print-shops.

Of Marine Fortifications.

S E C T I O N I.

Of the kinds and properties of Harbours:

169. A HARBOUR or PORT is an opening or inlet into the land, into which the sea runs with a depth of water sufficient to float ships, and where such vessels may lie secure from tempests and the sea.

As harbours may be of very different forms, so there may be a multitude of ways proposed for their defence; but here the business will be confined to a few of the more common situations.

Harbours in general may be distinguished into two kinds, namely, artificial and natural.

170. *Artificial harbours* are such inlets of the coast, as are rendered safe for shipping to ride there, by building about its entrance certain works called MOLES or PIERS, which defend the ships within from the surges of the sea without. When the *moles* or *piers* can be brought so close, as to be shut up by *fluices* or *gates*, the harbour is then called a BASON; but the inner part of a harbour, where the ships ride in still water, is usually called the *basin*.

All artificial ports of these kinds are easily fortified by building on the moles or piers, batteries, redoubts, or forts, which command the entrance into the harbour; but as these works are usually done at the time when the moles are made, there need be no more said of them in this work.

171. *Natural harbours* are those where the natural figure of the land forming them is such as contributes to the safety of the shipping, by sheltering the vessels from the fury of the sea; and this happens in various manners, as by a shoal lying off the harbour's entrance, which breaks the waves, and keeps the water still within; or by the points of land which form the harbour's mouth, stretching themselves so far into the sea, and coming so near one another, that the surges are broken at their entrance; or by a narrow inlet that runs into the land for a considerable way, where the shores near the entrance receive the shock of the waves, and render the upper parts smooth enough to anchor in, of which kind are navigable rivers; or by a large deep bay, where islands, or other obstructions, contribute to render a part secure for the riding of ships at anchor, &c. &c.

172. The properties of a good harbour are, a sufficient depth of water for large ships to enter at any time, whether the tide be in or out; good offing, and an easy access out of all danger from the winds; free entrance, without rock or sand-bank; the entrance not too wide to be easily barred and defended upon occasion; not subject to overflow, and where ships may lay close to the keys; where the vessels are sheltered from all winds by the high mountains surrounding the harbour, and from which there is an extended view of the sea; lastly, that the shipping there be in no danger of being set on fire, bombarded or cannonaded from sea by the ships of an enemy.

173. There

173. There are many places in which ships anchor, that lie open to the sea, and are safe to ride in only when the weather is calm, or when particular winds blow; such anchoring places are called *roads*.

S E C T I O N II.

Of the fortifying of Roads and Harbours.

174. FIRST SORT. *When a town lies open to the sea upon a curved or straight bold shore, and has before it a sufficient depth of water and good anchorage, within gun-shot of the shore.* As such places can afford shelter for shipping only at certain times of the year, when they are generally sure to have calm weather, or gentle gales, in which vessels may safely ride at anchor, they cannot so well be secured from the attack of an enemy, as places more inclosed. However, the shipping lying there during the season of trade, may be well defended by forts built near the water's edge on each side of the anchoring place; such forts being so contrived as to have two or three batteries, one higher than the other, furnished with many cannon, carrying shot from 24 to 48 pounds, will awe the ships of an enemy in general from undertaking any thing against the vessels that are lying in that road.

175. But in order to defend the town itself, there should be a rampart or wall, well flanked, built along the shore, beside the fortifications on the land side. The works along the shore should be carried so near to the water's edge, that were any troops to land under the cannon of a fleet, they might not find any ground to entrench themselves on.

176. Forts built on a bold shore, to which ships of war can come within musket shot, are in general liable to be easily taken, unless some precautions are used. For as the batteries on shore are seldom raised much above the water's level, in order to be more certain of their mark; the troops posted at the guns are liable to be commanded by the marines quartered in the round-tops, and other elevated parts of the ships. However, this may be prevented, either by driving several rows of piles (which are long pieces of timber, or the bodies of trees, pointed, and shod with iron at one end when necessary) in the water before the fort; or by fixing along the battery a kind of *shed* made with planks of musket-proof, and covered with raw hides or earth, that they may not be set on fire by combustibles thrown from the ships. These sheds are convenient not only to preserve the troops posted at the guns from musket-shot, during the time of an attack; but they would also preserve the cannon and carriages from the weather at all times; for the expence of a few rough planks, used now and then to repair such sheds, added to the first cost, might, perhaps, in a length of time, be found of less expence than the gun-carriages they would preserve; and should it turn out otherwise, the framing and planks might be prepared in time of peace, and set up only when there are apprehensions of an attack; but care should be taken to fix them so, as to be least exposed to the cannon from the ships. In such sheds, as they would be open behind, the smoke would be soon dissipated, and might be sooner thrown off by making

holes in the shed over every gun; which holes may be covered by a shore plank raised before them.

177. SECOND SORT. *When a harbour, being a bay, has a shoal or small island lying before its entrance:* Such a place is fortified by building a strong fort on the island, in a place where it can command the entrance on both sides, when the size of this island is not too large for this purpose; but when the mouth of the harbour, and the extent of the island is too large for one fort on the island to guard the entrance, then two or more forts should be raised in the most commodious places that command the avenues to the bay.

178. Beside the forts raised on such an island or shoal before a harbour's entrance, there should be others raised on the most convenient points of land forming the mouth of the bay; which will make the defence of the passage more secure, should the ships of an enemy pass the advanced defences.

179. When forts are thus built, it is not enough to contrive them in such a manner, that their batteries may annoy the shipping which attempt a forcible passage; but they should be also carefully fortified to resist attempts from an enemy ashore; for should this be neglected, a body of marines, or seamen, landing on the island or place where the battery or fort is, would frustrate the intention of such fortifications or defences, of which there are many instances to be met with in history.

180. As there may be several spots or points proper to erect the defences on, and which may command the entrance of the harbour in the manner described above, it is of importance to know which will have most advantages and fewest disadvantages; for both circumstances are to be brought into the account, and that chosen which has most of the former and fewest of the latter. Thus the soil should be the firmest and most capable to bear the cannon and building to be erected. The ground of a height sufficient to be out of the reach of tides and floods, and not much higher than is barely necessary to avoid those inconveniences; for the cannon commands best when near the water's level. The place should be difficult for an enemy to land in its neighbourhood; and if landed, where they may be most incommoded in their march to the fort—where succours may easily approach—where the troops on duty may without much trouble obtain the necessaries of life—and where there are the fewest noxious exhalations.

When the most convenient place for a fort or battery is chosen, the next thing to consider is, whether the work is to be temporary or perpetual; that is, whether the work is to serve only for a present emergency, or to be kept in repair under a probability of its being frequently attacked; and whether the work be temporary or perpetual, it is necessary that it be suited to the materials at hand, or that can be procured with the least trouble and expence.

181. It may frequently happen, that in such situations the passage between the island and main is rather too wide for cannon to command across; therefore, if the place is of sufficient importance, there may be many ways contrived to remedy this defect, when it is possible to be avoided. The best are those which oblige shipping to keep in one tract or channel; and when this can be accomplished, either by sinking old shipping, running out moles, or contriving to form sand-banks

banks or shoals, or by any other means that the situation of the place can furnish; forts also or batteries may be advanced so far into the water, as to command that channel; or if the passage cannot be reduced to less than two channels, then a fort should be erected, if possible, between them.

182. In the building of these works great care should be taken, that the foundations are laid sufficiently firm to support the superstructure; and as these places are generally low, either in marshy or sandy situations, a great number of piles should be driven into the soil, to the depth of 10, 20, 30, or more feet, according as they drive with more or less difficulty. If a quantity of such piles be driven, at the distance of 12 or 18 inches from one another, over the place intended for the foundation, and the tops of them be cut level some feet below the surface, a floor of timber may be laid over the tops of the piles, and the building raised on it.

183. THIRD SORT. *When the harbour is in a bay, and the points which form the entrance stretch into the sea, and approach one another within cannon-shot:* Such a harbour is fortified by building on both sides of its entrance one or more forts; and if it is possible, let a fort be also built within the harbour's mouth, in such a manner, that its cannon can rake the shipping fore and aft as they come in; for this would be a good reserve, should an enemy's fleet force their way between the forts which command the entrance. If there is no proper spot for such a fort, let others be erected on the most convenient points, that command the turning to the right and left within the mouth of the bay; for by these means an enemy will be obliged to endure a kind of running fire, which, if the forts be well constructed, he will scarcely be able to sustain.

184. FOURTH SORT. *When a harbour is formed by a cluster of islands:* Such a harbour is not difficult to fortify, when the channel between the islands is not too wide for the command of cannon from one or both shores, the directions how to place the forts in the foregoing cases being equally applicable to this. And in places where the channel is more than cannon-shot from either shore, the shipping that can ride there must depend upon the batteries ashore, as in the first case, when the shore is bold enough for the ships to run under the cannon.

185. FIFTH SORT. *When the harbour lies in an inlet or river some miles above its mouth:* If the passage to the port lies straight, and can be commanded from side to side, a fort built at each point of the entrance, and two others between them and the harbour, but not opposite to one another, unless the width of the channel requires it, will, in most cases, be a proper security for the shipping in such a harbour. And when the channel or river is winding, the forts should be built where they can command a reach at least; or be so placed at the bends, as to command two adjacent reaches; for as vessels must tack near the forts so placed, they will at those times be more under the command of the batteries, than they would be when sailing by them on a direct course.

In the directions for placing forts in this, and the other cases, there has been no mention of the figure, in which it would be most proper to construct them; for the engineer, who has the charge of such works, generally does, or should take care to adapt the figure to the spot; but for the sake of the mariner, it was judged proper to point out the methods usually taken on such occasions.

186.

Of the Figure and Size of Forts.

Beside the forts described as redoubts (Art. 68, 70), there are many others, such as squares, pentagons, hexagons, or the halves of these figures, which are fortified with entire bastions, by nearly the same kinds of constructions as are the polygons in the table, Art. 89; only the measures of the *exterior side, normal, and face*, are much less than those for a town, and usually near the following numbers:

Make the side or front about 180 yards; the normal one-seventh, or one-sixth of the side; and the face about twice the normal, or a little less; with a ditch, if necessary, about 20 yards broad; a rampart broad enough for a platform, and a parapet about 12 feet thick.

The exterior sides of forts may be considerably less or greater than 180 yards, even between the limits of 60 yards to 200, according to the size of the spot on which it is to be built, and the importance of the place it is to defend; for it would be a great absurdity to build a large expensive fort to secure a harbour or port of little more use than as a shelter to a few fishing-boats; or, on the contrary, to build a small trifling work to guard a haven, where many ships of the utmost importance are laid up, or riding at anchor.

It is not always necessary, or even convenient, to make these forts on figures perfectly regular; for the situation may require some of its sides to be shorter than others: neither is it necessary that the figures should be fortified with bastions, or half-bastions, at the angles; for there are many cases, in which it will answer the purpose equally well, or even better, to make a bastion on the side of a figure toward the middle; but then the faces of the bastion should be so drawn, that they may be raked from the extremities of that side, by a defence of at least 10 or 12 yards.

In many cases there needs no other than a direct defence from one, two, or three contiguous batteries, making one, two, or three sides of the figure given to the fort, suitable to the shore.

187.

Of proper Forts, and their Disposition.

If the place on which the fort is to be built is a spot surrounded with water, forming a channel on both sides, the figure is to be disposed so as to have one or two of its fronts turned toward each channel, by which means the batteries in the flanks will scour both up and down the stream, while those in the faces and curtains command the passage directly before them. That part to seaward may either have a front extended along it, or have one of the points of the figure directed that way, according as it may be judged most convenient; and if before these fronts there is any place at which an enemy can land, then one or more batteries should be so formed, that their guns may be brought to bear on that landing place; and if this be thought not sufficient, a small outwork should be built near that place, to make the landing more dangerous; and on account of the convenience of landing, the fort should be furnished with a ditch, covered-way, and glacis: the part next the harbour will be sufficiently secured by a line thrown up properly flanked. Should the situation be on a rock, where there is no danger of an enemy's landing, a good line, capable of covering the troops and cannon, will suffice. *If there is only*

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a channel on one side fit for shipping to pass through, that side should be fortified as in the former case; and lest the enemy's boats should get through on the other side, it should be also put in a state of defence: but here a slight redan, furnished with a few pieces of small cannon, may be found a sufficient defence against the boats.

188. When a fort is built on a point of the main, the kind of disposition used in the foregoing case, next to the channel, will also obtain in this: but it is necessary to take proper care of the land side, which in this case is more liable to be attacked than in the former. In the fortifying of the land side, the works should be proportioned to the strength of the enemy that may probably appear before it. For there are many places where there is no likelihood of ever seeing an enemy with a stronger force than can be exerted by a fleet of three or four ships of war; and as these cannot be furnished sufficiently for undertaking a regular land-siege, a well-flanked line, with a ditch, if properly defended, will secure the place against the attacks of sailors or marines unprovided with artillery: or should a few pieces be brought against the place, their passage to it will be very dangerous, unless they can be brought near enough to act under cover; and to leave such a cover, would be an unpardonable oversight in those who had the care of constructing that fort. But when the importance of a place may bring before it a large fleet, and a land army properly appointed, then the fortifications on the land side should be put in a state capable of sustaining a vigorous siege.

There are many low points on which batteries may be raised for the defence of a channel, over which a lofty ship may have a considerable command: in such ports, proper traverses should be placed, that the line of the battery be not raked by the ship's guns.

189. In the constructions of all forts it should be remembered, that a figure of, the fewest sides and bastions that can probably answer the proposed defence, is ever to be preferred, as the works on such plans are sooner executed, and with less expence; besides, fewer troops will serve, and they are more readily brought together in cases of necessity. And with regard to the executive part of such works, enough has been already said, only let it be observed that where stone and brick are scarce, and there is plenty of wood, then timber works are to be most used; and, on the contrary, stone or brick earth being plenty, and wood scarce, masonry is to be preferred: and let care be taken never to use sea-water in the lime, nor to make the parapet entirely of stone; for the splinters driven about by the enemy's cannon, will make it dangerous for the defendants to continue on their posts,

SECTION III.

190. *Of fortifying Harbours by Booms.*

Notwithstanding the forts built for the security of a harbour, or passage, there are many instances that might be produced to shew that such forts alone are not sufficient. The great Sir Walter Raleigh says, "In this age, a valiant and judicious *man of war* will not fear to pass by the best appointed fort of Europe, with the help of a good tide and a leading gale of wind; no, though forty pieces of great artillery open their mouths against him, and threaten to tear him in pieces.

"In the beginning of Queen Elizabeth's reign, when Denmark and Sweden were at war, our Eastland fleet, bound for Liefland, was forbidden by the king of Denmark to trade with the subjects of his enemies, and he threatened to sink their ships if they came through the streights of Elfsineur. Notwithstanding this, our merchants, having a ship of her majesty's, called the *Minion*, to defend them, made the adventure, and sustaining some volleys of shot, kept on their course. The king made all the provision he could to stop them on their return. But the *Minion*, commanded (as I take it) by William Burrough, leading the way, did not only pass with little loss, but did beat down with artillery a great part of the fort of Elfsineur, which at that time was not so well rampar'd, as perhaps now it is; and the fleet of merchants that followed him, went through without any wound received. Neither was it long since, that the duke of *Parma*, besieging *Antwerp*, and finding no possibility to master it otherwise than by famine, laid his cannon on the bank of the river so well to purpose, that he thought it impossible for the least boat to pass by. Yet the *Hollanders* and *Zealanders*, not blown up by any wind of glory, but coming to find a good market for their butter and cheese, even the poor men attending their profit, when all things were extreme dear at *Antwerp*, passed in boats of ten or twelve ton, by the mouth of the duke's cannon, in despite of them, when a strong westerly wind and tide of flood favoured them; as also with a contrary wind, and ebbing tide, they returned back again: so as he was forced in the end to build his *stockado* overthwart the river, to his marvellous trouble and charge. The fort of *St. Philip* terrified us not in the year 1596, when we entered the port at *Cadiz*; neither did the port at *Punta*, when we were entered, beat us from our anchoring by it, though it played upon us with four demi-cannon, within point-blank from six in the morning till twelve at noon. The siege of *Ostend*, and of many other places, may be given for proof, how hard a matter it is to stop the passage of a good ship, without another to encounter it. Yet it is true, that where a fort is so set as that of *Angra* in *Tercera*, that there is no passing along beside it, or that ships are driven to turn upon a bow-line toward it, wanting all help of wind and tide; there, and in such places, it is of great use and fearful: Otherwise not."

Since Sir Walter's time, the Sound has been better fortified, yet in 1700 Sir George Rook passed it, notwithstanding the Danish fleet lay to impede his passage. The actions at Londonderry, Vigo, Porto Bello, Carthage, and at many other places, are all sufficient proofs, that nei-

ther

ther forts nor castles can stop the enterprizes of the brave; and therefore it has been judged proper on many occasions, besides forts and batteries, to lay booms and other obstructions in a stream, to secure the shipping there from the attacks of a powerful enemy.

191.

To lay a Boom.

Provide a great number of wooden battlings or spars of about 20, 30, or 40 feet long, more or less, and between 5 and 10 inches diameter. Then moor two boats, having a sheet-anchor in each, in the place near one side of the river where it is intended the boom shall begin; bend two cables to these anchors, and round them place the spars or poles, frapping on each with rattling stuff, or better with four-inch rope, until the boom is 7, 8, 9, 10, or more feet diameter (according to the hands employed), the cables being in the middle; next, with iron hoops rivetted together, worm the boom, and drive through the hoop a nail into almost every spar. After having wrought a good birth for the anchors, drop them, and continue the work till it is brought near the other edge of the river, and there drop two anchors more, with the cables bent to them. Then over all lash the spare yards and top-masts with the top-chains, so far as the channel goes.

To that part of the cable within the boom, over the channel, let two or more cables be fastened, and bent to anchors laid down the stream; over the clinch of these cables let battlings or spars be wrought for near ten fathoms down the stream, that the enemy may not cut these cables. These will be serviceable when the enemy's ships come *stemlings* against the boom; for if he force it in one place, the whole will not be opened by that fracture.

In places where wood is scarce, and proper spars are not to be readily had, or in cases where there is not time sufficient to prepare them, it may be found sufficient to woold two cables together with old ropes, lashing to them the oars, top-masts, and yards, and worming the whole about with iron hoops: and let every part be well *payed* with pitch, and small gravel strewed on it while the pitch is warm. A boom so prepared cannot be easily cut.

It is in most cases convenient to have the boom so contrived, as to open at one end for the passage of vessels; and this may be done several ways, one is to let one end of the cable be clinched to an end of a large mooring-chain, the other end floating with a buoy, and this end fixed to the ring of the anchor by a shackle. Now the chain being loosed from the anchor at the ebb with a slack hawser fixed to it, the boom will swing down the stream during the ebb, and upon the flood the boom may be relaid, if the enemy appear in sight, which he must do the first of the tide, for upon the ebb there is no danger of his coming; because, if the wind be right in, a prudent enemy will not adventure against the tide, a ship then making such wild steerage; and should she ground, she must lie there till flood, which may prove fatal to her from the batteries ashore; and against both wind and tide the enemy cannot come in. On the contrary, should the boom be carried up the flood, and the enemy appear at the beginning of the next flood, the boom cannot be relaid till the ebb, and before that time the enemy may have accomplished his design.

192. If

192. If there be good store of timber at hand, a *stockado* may be made by driving several rows of piles in the channel before the boom; or should the depth of water be too great for this work, the trees may be usefully applied in making a raft to ride before the boom by good anchors, so that the cables be made too fast for the enemy to cut them. These rafts may be of singular use, by making fires on them, when the enemy appears, which will put him into some consternation, and perhaps may cause him to chop to anchor, and lose time or his tide; and this may be done each flood, observing not to have the smoke drive into the works, which might give the enemy too great an advantage.

193.

To lay a Boom in a straight Channel.

Suppose the wind for the most part to blow obliquely across the river or channel on the starboard quarter going up the river, if the boom be laid directly athwart the channel, the ships coming with the tide of flood, and a leading gale will run stemlings against it, and possibly break it by striking with a force that comes direct; whereas, could the boom be laid obliquely athwart the river, nearly in a line with the wind, so that the ship must take it with her bow, the blow would be diverted by the ship's casting: because in this position the enemy cannot run stemlings against it; for in sailing up the river, the ship must be near before the helm; and to bring her head to a boom laid obliquely, the helm must be put down, and then it is ten to one whether she come to so nicely as to take the boom: not to mention the mistakes which in the confusion may be committed by the man at the *helm*, and him upon the *cond*, nor the smoke; for exclusive of all these, it may be taken for granted, that the ship would cast along-side the boom; and then the batteries at the end of the boom on the larboard side would rake him fore and aft, while the opposite batteries on the starboard side playing on his broadside with *double-round* and *partridge*, must make a great slaughter among his men cutting at the *boom*. And should he not swing along-side the boom, but lie stemlings against it, the batteries on the starboard side of the river, which are to be made above the weather end of the boom, will rake him fore and aft, while those on the larboard side play on his quarter or broadside.

194. The ships within the boom, which it is to protect, should be moored in a kind of half-moon with their broadsides flanking the boom. And several old ships, or those which are the least useful, may be sunk as soon as a signal is given from one of the forts, signifying that the boom will be cut. For this purpose, those ships should have large scuttles ready cut: and for a farther security it would be very proper to have a small boom to divert the enemy, that the ships may be sunk in the channel before he boards them.

As to the rest of the ships, they are left to the judgment of their commanders: and if there is no other remedy, the people may get ashore to windward if they can, and there make the best defence in their power against the enemy's boats and fire-ships. From duly weighing the whole of these circumstances it will be found, that the chief strength is in the boom;

boom; therefore if a double, triple, or fourfold boom were laid, if the materials could be procured, and the value of the shipping and cargoes were of sufficient importance, it would make the place so much the stronger, and the enterprise of the enemy more hazardous. In stretching these booms, the trouble of many anchors may be spared by making all the cables fast to the first, and so let them float in a bight, and by a small anchor ride upon the ebb, to keep clear of one another.

195.

To lay a Boom in the Bend of a River.

From the point formed by a bend stretched two booms across the channel, one toward the middle of the opposite bight, and the other so much higher, as to lie directly athwart the channel, leaving a kind of angular space between them.

Next the point from whence the two booms stretch, erect a proper fort or battery to command the channel below and above the bend.

On the other side of the river erect another fort or battery against the bight a little above the end of the lower boom, and so disposed, that its cannon may rake the channel coming up, as well as command both the booms.

From such a disposition, it is a great chance if a ship answer her helm so timely in *bearing* or *loosing* about the point, as to take the boom stem-lings, and if she smite it with her bow, she casts; and in either case she will be raked fore and aft by one fort, and have her broadside battered by the other.

Let some old vessels be fitted up for fire-ships, and placed between the two booms; from each ship let two hawfers be carried ashore, one on each side, and fixed to crabs or capstans set up; so that as soon as the enemy has passed the first boom, these ships being set on fire, and heaved in their way, nothing can hinder the enemy's destruction. As soon as fire is set to the train, the boat may pull ashore under covert of the ship without any apparent danger; for such will be the enemy's consternation, that they will soon leave firing. The hawfers may be fastened to clamps below the water-line, that they be not burnt, nor in sight of the enemy to cut them. If the fire-ship is clapt aboard the weathermost ship, they may be both heaved together aboard another to leeward.

The ships to be defended, may be moored in a half-moon, with their broadsides so laid, as to batter the enemy when he attempts the boom: and if other works than what are here directed be judged necessary, they must be adapted to the situation of the place.

196. When no strong attacks by land are to be feared, the mooring of ships behind a point is best on account of laying the boom. Now should the boom be forced, which must be upon the flood, a fire-ship, instead of falling on board a ship thus moored, will, by the tide, be hurried beyond her; and if the place be any ways favourable to the ships moored there, it will be found impracticable to board a ship thus moored, with such a wind and tide as the enemy must have to break the boom, unless he expose his boats in carrying out an anchor to *warp* over, which will be a very dangerous attempt; or some unaccountable accident intervene.

197. It

197. It may be objected that ships thus moored cannot bring their broadsides to bear upon the enemy when coming to force the boom; and that they may be battered by the enemy over the point. To this it may be answered, first, It is no matter whether the broadsides do bear or not, for perhaps it might be the best way to get the guns ashore, if there is time, to be there used; and to put the smaller sort only on the lower deck, and turned to flank the boom. Secondly, The enemy will have but an uncomfortable *birth* in lying to batter the ships over the point, as they will have to deal with the fire from the fortifications ashore. What is here said, is only to be understood when five or six ships are to be defended; for the wake of a point would not hold any considerable fleet.

198. *Maxims to be observed in fortifying a harbour and mooring the shipping in it.*

I. Let all the land-marks be removed that may direct the enemy's steerage into, or up the river or harbour, when there is a probability of an attack.

II. Choose such a place, if possible, for erecting the works on, as cannot be laid under water, either by hasty rains, or by any art of the enemy.

III. Let the eminences which command the works within cannon-shot, be secured by erecting small forts on them, furnished with small cannon.

IV. All woods within cannon-shot of the fortifications are to be cut down, and the timber employed about the works.

V. Secure a spring of fresh water by a fort and proper guard.

VI. Take all the buoys from the anchors that ride the booms, that the enemy may not trip them.

VII. Let the powder and other munitions be separated and kept in different places, that if an accident happens, the whole may not be destroyed.

VIII. The ships should not be posted near any town or village, unless they are intended to cover that place, or the thing be unavoidable; lest the shot and bombs which miss the ships destroy the town.

IX. The ships should never be moored before the fortification.

X. Moor the ships so as to rake the enemy fore and aft when he batters the works.

XI. Let not the ships when moored touch one another, that the enemy may be obliged to burn each ship singly.

XII. Unrig the ships, and strip the shrouds from the mast-head, that the grapplings of fire-ships may have no hold.

XIII. Let the sails be carried ashore for tents, and most of the gunner's stores; that if the worst happen to the ships, there may be store of ammunition for the forts.

XIV. Unless the cargo be ashore, let not the chests nor clothes of any person, from the captain to the swabber, be carried out of the ship; that every man may have some inducement to exert himself in the defence.

XV. Let outguards and centinels be placed upon and near the banks of the river or harbour; and let some hands in nimble boats, armed, pass down the stream each night to watch the motions of the enemy.

SECTION

SECTION IV.

199. *Of the mooring of ships in fortified harbours.*

Before the boom is laid, it will be necessary to appoint the place where to moor the vessels, that they may be best secured from the enemy's fire-ships, and yet annoy their men of war; and as this can be only done either in the stream or out of it, the advantages and disadvantages in both cases will be here considered.

200. *Considerations in mooring with regard to the stream.*

FIRST. *The advantages an enemy has of a ship moored in the stream.* A ship moored in the stream will find some difficulty in bringing her broadside to gall an enemy in his approach, who always comes with the stream; and if the tide runs too swift for one to lie athwart, it certainly does so for the other; both having ground tackle equally good.

2d. In this situation there is no hindering a fire-ship, that has passed the boom, from being aboard you, as none but the chase-guns can be brought to bear on it; and should you heave athwart, the enemy will be the surer of grappling you, unless by bringing your whole broadside to bear you sink him; for if the officer, through want of courage, should forsake the fire-ship, yet the tide will bring it aboard; besides, in such a position the enemy's ships of war may board you, and then your batteries ashore are useless.

3d. In riding in the stream the cables are exposed to the enemy; which being hit by a chance shot, the ship will swing upon the tide, and the enemy have the opportunity of raking you fore and aft; and if the enemy has any conduct, he may lay his anchors so, that his cables shall be secured from your shot.

4th. Should you moor athwart the stream, the enemy may drop a small anchor out astern, veer athwart your hawse, and so constrain you to alter your position, or rake you fore and aft.

5th. In riding athwart the stream, the cables by bearing a more than ordinary strain, are apt to break, or start an anchor; then the ship swinging on the tide, it is a great chance but the other anchor starts, and she swings to leeward. But these advantages are on the enemy's side only while the tide sets in; for the defendants have them when the tide sets out: therefore, in such places where the stream runs continually out, the best way is to moor in it, if the wind does not blow always in.

201. *SECONDLY. The advantages a ship moored in a stream has over an enemy.*

1st. A ship moored athwart the tide lies convenient to rake an enemy fore and aft in his approach, and so may do him a considerable damage before he is athwart the stream to batter.

2d. In riding thus in the stream, according to the common situation of rivers, the enemy cannot batter you under covert.

202. *THIRDLY. A ship moored out of the stream has these disadvantages.*

1st. That she cannot rake the enemy fore and aft so well as while she lies in the stream, unless by some particular situation of the place.

2d. The

2d. The enemy's men are not much exposed in mooring; for he needs only to drop his anchor, and he may veer along your side; or, if you lie athwart the river, across your hawse: but this may be prevented by riding in the wake of a point; for should the enemy drop anchor before he is about the point, he cannot veer along-side; and if he let go his anchor after he is about the point, he may be astern before he is brought up.

203. *FOURTHLY. A ship moored out of the stream has these advantages.*

1st. There is no danger of the fire-ships driving aboard her, unless directed by a strong wind. And for the same reason, the enemy cannot be athwart your hawse, unless he tows there with his boats, and then they and their crews are exposed to your cannon.

2d. A ship thus moored is in less danger of driving, should her cables be shot.

Considerations in mooring with regard to the wind.

204. *FIRST. With regard to windward.*

Besides the advantage of being free from the smoke, you may cause the enemy to drive to leeward should you hit his moorings; and if he tries to heave off by carrying an anchor to windward, his boats will be exposed to your cannon; and if the boats lay to pass his ship, while he heaves, will be raked fore and aft, which must do great execution among his men while they stand thick at the capstan: but it is highly probable, a ship so grounded could not be got off.

When to windward, the cables are covered from the enemy by the ship, and may be seized to clamps and cleats nailed to the side, and so the mooring secured from random-shot. And this ought to be carefully done for preventing the only disadvantage that attends ships moored to windward, which is, that if their cables are shot, they drive out upon the enemy, or swing head to the wind; if the former, they may be boarded by the enemy's fire-ships, or ships of war, and then your precautions are rendered fruitless; if the latter, they may be raked fore and aft by the enemy; and if neither of these happen, the ship may drive to leeward and be grounded.

205. *SECONDLY. With regard to leeward.*

A ship so moored cannot prevent the enemy's being sent on board, unless a shoal or stockado lie between them.

In this position, should you shoot the enemy's cables, through his carelessness in covering them with his hull; yet as he drives ashore, or upon you, his boats are covered with his hull, while they carry an anchor to windward to heave off.

Besides, your moorings lying to windward are exposed to the enemy; and should they be cut, you will swing head at wind, and in that position be raked fore and aft; if you attempt to carry out an anchor to heave your broadside against the enemy, your boats will be too much under his command; indeed, instead of carrying out an anchor it may be best to clap a spring upon the cable, but this will fail if the ship is too near the shore.

Upon the whole, it appears best to moor to the windward in the wake of a low point, when such a situation can be obtained; but the circumstances being so various, it must be left to the judgment of the commander, who, if he rightly considers what has been said, will chuse the best.

SECTION

SECTION V.

206. *Of some remarkable actions concerning the attacks of ships in fortified harbours.*

Having shewn the methods that have been directed by experienced men, to be used in the defence of harbours, we shall now think of closing this work with the accounts of some of the most remarkable actions recorded within the last 100 years, in which the English have had any share. This was thought useful on two accounts; first, as examples to the preceding precepts; and, secondly, to point out to the young mariner the means by which many have acquired great reputation and honour.

207. *The battle of Santa Cruz, in the year 1657.*

Santa Cruz is a town and bay on the west side of the island of Teneriff, one of the Canary islands. The bay, which lies rather open than inclosed, has deep water near in shore; but the best anchoring is about half a mile from shore, in 30, 40, or 50 fathoms water, black slimy ground: if there be many ships, they must ride close one by another. The shore is in general high land, and in most places is steep to the water.

Admiral Blake lying with some ships near Cadiz to watch for the return of the Spanish plate fleet, had intelligence they were in the bay of Santa Cruz, in the island of Teneriff; he broke ground the 13th of April, and on the 20th arrived at Santa Cruz, where he found the Spanish fleet, to the number of sixteen, moored in the bay in a half-moon. Near the mouth of the bay was a castle well furnished with near 40 heavy cannon; and besides that, there were seven forts round the bay, with 6, 4, or 3 great guns in each, all united by a line of communication from fort to fort, and well lined with musketeers. *Don Diego Diagues*, the Spanish general of the fleet, upon sight of the English fleet, caused the ten smaller ships to be moored close to the shore, and set six great galleons, well manned, farther out at anchor, with their broadsides to sea: In this posture the Spanish admiral vainly thought himself so secure, that a Dutch merchant ship going out of the harbour, he sent a message by him to *Blake*, that he might now come if he durst.

The English admiral, having well viewed their posture, saw it would be impossible to bring off the galleons; however, he resolved to burn them, and to that end sent in Captain *Stayner*, commander of the *Speaker* frigate, with a squadron to attack them. He soon forced his passage into the bay, whilst other frigates entertained the *forts* and *lines* with continual broadsides; these were presently supported by *Blake* himself, with the whole fleet, who placing some of his ships to batter the castles and other forts, he with *Stayner* continued to engage the galleons; over which, in six hours, he gained (notwithstanding they had reinforcements of men several times from the shore) a complete victory. The Vice-admiral and Admiral were blown up in the engagement, and the rest driven ashore; where, notwithstanding the fire from the forts, they were all set on fire by the English, and every one of them was burnt to the water's edge. They had no sooner done this, than the wind luckily turned, and carried the fleet, without the loss of one ship, out of the bay, and put them safe to sea again.

208.

The action of Londonderry, in the year 1689.

Londonderry is a small but pretty strong town in the north of Ireland: it stands on the west side of the river *Loughfoyle*, about three miles from a lake of the same name; which is about ten miles broad and fifteen miles long, communicating with the sea by a strait of about a mile in breadth, so that the town stands about eighteen miles from the sea. The river next the town is about $\frac{1}{4}$ of a mile over, and keeps this breadth nearly between the town and lake, where its mouth is defended by Culmore fort, which is a large square with four bastions.

This town was besieged by the Irish and French in the year 1689, and the garrison brought into great straits for want of provisions, the besiegers having strongly fortified the river. There was a boom framed of a chain of cables, covered with timbers, stretched across the river about two miles below the town, from a point on the east side: each end of the boom was defended by a fort. Between the boom and Culmore fort were two other forts, one on each side the river, and another fort above the boom opposite the town. The sides of that narrow river were intrenched and lined with musketeers, and several boats were sunk, and stockadoes drove, armed with large iron spikes.

Notwithstanding all these preparations the boom was forced, the town relieved, and the siege raised, by the assistance brought by three ships only, in the following manner: The *Montjoy of Derry*, commanded by Captain *Browning*, and the *Phœnix of Colrain*, by Captain *Douglas*, being both laden with provisions, were sent towards the town, under the convoy of the *Dartmouth* frigate, commanded by Captain *John Leake*. They were forced to stand a furious fire of the enemy from Culmore fort, and from the forts and intrenchments on both sides of the river, which they received and returned with the greatest bravery imaginable. The *Montjoy* made a little stop at the boom, occasioned by her rebound, after striking and breaking it, so that she run a-ground. Upon this the enemy gave a loud and joyful shout (though a dreadful one to the besieged), fired all their guns upon her, and were preparing their boats to board her. The trouble and concern of the besieged, to see their last hopes disappointed, is not to be expressed; but by great providence, firing a broadside, the shock loosened the ship so, that she got clear and passed the boom. Captain *Douglas* was engaged all the while, and the *Dartmouth* gave the enemy very warm entertainment, till at length the three ships, having overcome the great difficulty of breaking and passing the boom, got into the city, and brought unspeakable joy and transport to a garrison, which reckoned only upon two days life, having nothing left but nine lean horses, and a pint of meal to each man. This brave and successful undertaking so discouraged the enemy, that they raised the siege the next day, and retreated by night in the utmost confusion; but made a most miserable havock in the country, by robbing and burning all before them for several miles.

The boom appears to have been laid directly athwart the stream, and so was easier to force, than if it had been laid obliquely across.

209. *The*

209.

The action of Gibraltar, in the year 1693.

The English fleet, under the command of *Sir George Rooke* and *Sir Thomas Hobson*, were convoying a very large fleet of merchant ships toward the Mediterranean; but falling in with the French fleet, under the command of *Admiral Tourville*, the English admiral gave the signal for the merchantmen to shift for themselves. Among others, four heavy-laden Turkymen; namely, the *Shandois*, the *Italian Merchant*, the *Asia*, and the *Loyalty*, stood away for the Spanish ports, and put into the bay of Gibraltar; where the commanders of the Turkey ships, being hindered from prosecuting their voyage by some dissension on board, and the fear of the French fleet, thought proper to fortify themselves.

For this purpose the commanders posted their four ships in a line within the new mole, which stretches to the NW., with their broadsides flanking toward the north, or entrance into the mole; the ships were unrigged, and consequently having no sails to manage, they turned all hands to the cannon, bringing as many as they conveniently could to bear on one side.

On the SE. end of the mole, or land-side, was a castle, in which were mounted ten small cannon, four pointing into the bay toward the west, three commanding the mole, and the rest flanking the NE. shore. Opposite to the mole-head was a kind of redent, very advantageously built to flank the entrance into the mole; but neither on this, nor the mole-head, had the Spaniards any cannon. From the castle there ran northward a line of communication, or a strong stone wall, to the south end of the town, where was a battery of cannon, but too far from the mole to be of any service in defending it.

The English stretched a cable from the mole-head to the redent, the ends being bent to two sheet anchors, and to this cable they lashed their *spare-yards* and *top-masts*. Upon the mole-head were planted six of the *Shandois's* guns to flank the boom, and this battery was committed to the care of some English seamen, who behaved themselves very well. The commanders intended to plant some guns at the other end of the boom upon the redent, but being obliged to go through the castle, the draw-bridge broke, and down went the first gun that came upon it into a ditch near forty feet deep, with some of the *Shandois's* men; by this it may be judged in what condition the Spanish works and garrison were.

In this posture things were, when the French came into the bay with fourteen or sixteen men of war and two bomb-ketches, and standing within shot of the castle, the Spaniards shewed their dexterity in managing their ordnance by firing about one shot in half an hour. The commanders perceiving their awkwardness, sent a quartermaster from on board the *Shandois*, and the gunner's mate of the *Loyalty*, to their assistance, and some dozens of cartouches; but through want of judgment in the Spaniards they were both blown up. All this time not a ship could bring a gun to bear, and so without any damage the enemy passed by into the bay, where they anchored.

In the afternoon they sent down two *men of war* to view in what posture the ships lay; as soon as they came within shot, the English fired briskly at them; but before many broadsides were returned, they stood away to

their squadron, and continued quiet that day. Next morning a ship of upwards of fifty guns came toward the boom, and it proving calm when she came within shot, there was pretty brisk firing on both sides, on which she endeavoured to row off, but her boats were sunk from the battery on the mole-head, and had not boats come from the squadron to her assistance, she had most certainly been sunk, having above 100 cannon playing upon her from the English. The enemy finding such entertainment provided for them before the boom, sent off four *men of war* and the two *bomb-ketches*, which lying to the southward of the mole, and firing over it, raked the English fore and aft; who, on account of their former disposition, could not bring one gun to bear upon the enemy, either from the four ships, or from the mole; under these circumstances, the commanders judged it best to sink the ships. In the evening the French stood out of the bay; and next day stood in again; and having posted some *men of war* and their two bomb-ketches against the castle and mole, they sent in a store-ship which they had turned into a fire-ship, and burnt the upper works of three sinking ships; for the *Italian Merchant's* fore-castle being under water, saved the Shandois.

210.

Disposition of the English fleet at Cadiz.

The 16th of October *Sir George Rooke* arrived in the bay of Cadiz with the fleet under his command, and on the 21st it was resolved in a council of war, that as there were but 30 ships of the line, which was not a force sufficient to oppose the enemy, who were expected to be above double that number, all that could be proposed till the fleet should be reinforced from England, was to protect the trade. But lest the French should appear at Cadiz before this reinforcement arrived, it was agreed that the ships should be removed within *Puntal* castle, and formed in three lines; which was all that could be done, the ships being in general but half manned, and the Dutch ships very foul.

These three lines were to be as follows: the first to consist of the largest English ships, to lie from *Puntal* thwart the channel to the creek's mouth called *Truccadero*, next within the north castle; the second to be composed of the smallest English and Dutch ships, along the shoal on the south side of the harbour; and the third to be of the largest Dutch ships, to begin from the upper end of the second line, and to trench away thwart the channel, to the mouth of the upper creek, which goes to *Port Real*; and the small frigates, bomb-vessels, and fire-ships, were to be posted to the best advantage, as the wind and other circumstances might permit. However the fleet was not attacked, and about the middle of March *Sir George* put to sea on his return to England, and arrived in the Channel on the 22d of April.

211. *Fortifications in the harbour of St. John in Newfoundland, 1697.*

Commodore *Norris* being sent with a fleet to recover Hudson's bay, put into the harbour of St. John in Newfoundland, upon hearing that a large French fleet were on the coast of North America; and not knowing the strength of the enemy, he judged it prudent to secure his force, that
it

it might be employed in the service he was sent on. He therefore put his squadron into a line of battle, which was composed of four fourth rates, two fifth, and two sixth rates, with two fire ships, two bomb-vessels, and a hag-boat. Two booms were laid across the harbour, and Colonel Gibson's regiment, that was carried by the squadron from England, was disembarked, and several guns mounted on the batteries ashore.

When the French squadron came in sight, the foregoing disposition was altered. All the *men of war* lay in a half-moon to the harbour's mouth; and each ship's broadside commanded the two booms: Colonel Gibson's regiment was posted at the two batteries, and about the harbour's mouth, and Captain Richards (who was the engineer for fortifying the harbour) was making such works as he judged necessary on this occasion; and that the squadron might be better able to do service, all the men were taken from the merchant ships and put on board them.

The French fleet made no attempt on the harbour; but, on the contrary, were glad to find that the English had been misinformed of their strength, and so shaped their course for Europe.

212.

The battle of Vigo, in the year 1702.

Monsieur *Chateau-Renault* arriving early in September at Vigo in Galicia, with the Spanish galleons under his convoy, received information of the English and Dutch fleets being before Cadiz; of which timely intelligence he made all the advantage he could in preparing for their reception.

In the upper end of *Vigo bay* is a river running into the bay; up this river is *Redondella* harbour, which is surrounded with hills in such a manner, as to be capable of being made very strong, the harbour's mouth not being above a musket-shot over. On the north side the entrance was a battery of eight brass, and twelve iron guns, and on the south side a platform with twenty stately brass guns, and twenty good iron guns, besides a stone fort, with a trench about it, mounted with ten guns, and defended by 500 men. A little above the battery on the right, from two points in a narrow gut, was stretched a cable, to which was lashed masts, yards, casks, &c. with their top chains, and frapped about with four-inch rope very thick. The bight of the boom was rid by three anchors down the stream, that if the English ships came steming against it, they might not bring home the anchors upon the shelf at the end of the boom; or if they cut it in one place, the whole might not be open. To flank the boom, there was moored the *L'Esperance*, a ship of seventy guns, on the south side, and the *Le Bourbon*, a ship of seventy-six guns, on the north side; also five men of war, of sixty and seventy guns each, lay moored with their broadsides flanking the gut. The French admiral, to give him his due commendation, had taken all human precautions to secure his fleet.

When the confederate fleet came before the place, Sir George Rooke called a council of war, and it was resolved to attempt the forcing of the harbour the next morning. As soon as the land-forces were got on shore, the 12th of October in the morning, the admiral gave the signal to weigh, the line was formed, and the squadron was briskly bearing up to

the boom; but when the van was got within shot of the batteries, it fell calm, so that they were necessitated to come to anchor. A fresh gale springing up not long after, Vice-admiral *Hopson*, in the *Torbay*, being next the enemy, immediately cut his cables, clapt on all his sails, and bearing up directly against the boom, amidst all the enemy's fire, broke through it at once, cast anchor between the *L'Esperance* and *Bourbon*, and with unparalleled resolution received several broadsides from them. The rest of Vice-admiral *Hopson*'s division, and Vice-admiral *Vandergoe*'s, with his detachment, having weighed at the same time, sailed abreast toward the boom, to add the greater weight and force to the shock, but being becalmed, they all stuck, and were obliged to hack and cut their way through; but a fresh gale blowing again, the Dutch Vice-admiral made such good use of it, that having hit the passage which the valiant *Hopson* had made, he went boldly in, and made himself master of the *Bourbon*. All this while Admiral *Hopson* was in great danger, for being clapt on board by a French fire-ship, by which his rigging was presently set on fire, he expected every moment to be burnt; but it very fortunately fell out, that the French ship, which indeed was a merchantman laden with snuff, and fitted up in haste for a fireship, being blown up, the snuff in some measure extinguished the fire, and preserved *Hopson*'s ship from being consumed, which however received very considerable damage in this action. At the same time Captain *Bokenham*, in the *Association* of ninety guns, laid his broadside against a battery of seventeen guns on the left side the harbour, while Captain *Wyvell* in the *Barfleur*, a ship of like force, was sent to batter the fort on the other side. Thus for a long while there was a considerable firing of great and small shot on both sides, till the French admiral seeing the platform and fort in the hands of the English, his fire-ship spent in vain, the *Bourbon* taken, the boom broken, and the confederate fleet pouring in upon him, he set fire to his own ship, and ordered the rest of the captains under his command to follow his example, which was done in great confusion; yet could he not be so punctually obeyed, but that several men of war and galleons were taken by the *English* and *Dutch*.—In this action it should be observed, that the success of the fleet was in a great measure owing to the land-forces under the command of the Duke of *Ormond*, who not only drove away several bodies of troops destined for the defence of the shore, but also took the castle and platform on the south side, which might otherwise have done great damage to the fleet.

213.

The action of Carthagena, in the year 1741.

Carthagena, one of the best towns the Spaniards have in South-America, lies on the Caribbean Sea, almost due south of the east end of Jamaica. An irregular shaped peninsula, running in the direction of the sea-coast, nearly north and south, forms a fine harbour of about ten miles long, and in some places about two miles broad: near the north end of this harbour stands the city, its NW. side being washed by the sea, which being very shoal and rocky to some distance from the shore, together with a great surf, hinders the town from being molested to sea-ward. On the south end of the harbour is an entrance called Boca-chica, of about one

one third of a mile broad, with sufficient water for the largest ships. The north side of this entrance is near a mile long, running east and west, and the south side not above half that length; just within this passage, on the south side, lies a small island, between which and the east end of the north side is about one fourth of a mile.

In the spring of the year 1741, England being at war with Spain, an expedition against Carthagena was undertaken by the English; the fleet was under the command of Admiral *Vernon*, and the land force was conducted by General *Wentworth*: the Spaniards, apprized of the design, made an excellent disposition for the reception of their enemies, who found the following impediments to their sailing into the harbour.

Near the east end of the north side of the entrance, stood a well-built regular square fort called Boca-chica castle, two of its bastions commanding the passage, the walls of stone, and mounted with 82 cannon and three mortars; and at the west end were the forts of St. Philip and St. Jago; serving as redoubts to the castle, and guarding a small bay where there was tolerable landing. On the western end of the south shore, called the Barradera, was a fascine battery of 15 heavy cannon, about five of which commanded to sea-ward, and the rest flanked the west shore of the other side, and even the castle itself. On the island stood St. Joseph's fort with 21 guns; between this fort and the castle was stretched a boom obliquely across the passage; and above this boom were moored, in a line commanding the boom, four men of war, each carrying from 60 to 70 guns.

Three English 80 gun ships, in about three hours cannonading, obliged the enemy to retire from the forts of St. Philip and St. Jago; and the army was landed, encamped, and formed the siege of the castle: eight days afterward, the camp having been much galled by the Barradera battery, it was attacked, burnt, and most of the guns spiked, by the boats of the fleet, under the command of Captain *Boscawen*: but the Spaniards, knowing the value of that battery, repaired it; and by its fire so much interrupted the progress of the army, that seven days after its first destruction, three ships were ordered to lie against it, and the boats of the fleet were again manned, under the command of Captain *Watson*, when they effectually destroyed the whole battery. Two days after, on the 25th of March, while Boca-chica castle was storming by the army through the breach they had made, the Admiral sent the ships boats, under the command of Captain *Knowles*, to attack St. Joseph's fort, which he took possession of about ten o'clock at night, and also of the Galicia, the Spanish admiral Don Blafs's ship, the Spaniards, upon hearing the English huzzas at the castle, having abandoned the castle, St. Joseph's fort, and the four ships, which were already scuttled for sinking to barr up the passage; but the enemy, in the utmost panic, had not time to follow their orders, so that only two of their ships were sunk, and a third they set on fire. Captain *Knowles* immediately ordered the boom to be cut, and opened the passage, through which Admiral *Vernon* with the fleet sailed the next morning: and now the English having possession of the harbour, the necessary dispositions were made for gaining the town: but here they failed; and the officers thought it better to retire with their fleet and army, than to stay longer in a country, the un-
wholesome

wholesome climate of which was infinitely more to be dreaded than the utmost efforts of its timid inhabitants.

214. *The proceedings of the English in the river Hughley, in Bengal, in India, 1757.*

In the year 1756, the government of Bengal devolving on a nabob in the French interest, he, on a frivolous quarrel, dispossessed the English of most of their settlements on the river Hughley: but the governor of Calcutta, and many of the factory, secured themselves, and part of their effects, on ship-board, and fell down the river out of the nabob's reach. To regain these places, and to punish the nabob and the French for their perfidious dealings, Admiral Watson, commanding the fleet, and Colonel Clive the land-forces, entered the river Hughley. On the 15th of December the army was landed, and, in conjunction with the fleet, attacked and took every place of defence on the river up to Calcutta, which they retook on the 2d of January, 1757; and before the 11th they took the town of Hughley, which they plundered, and afterward destroyed.

On the 5th of February, Captain *Warwick*, at the head of a party of seamen, by the Admiral's order, joined Colonel Clive, and the same day they gained a victory over the nabob's army, which obliged him to make a peace, very advantageous to the English.

Afterward, Colonel Clive having taken all the French posts in the neighbourhood of Chandernagore, except one between the fort and the river, Admiral Watson, who was proceeding up the river to second the land operations, found himself obliged to come to anchor about two miles below the place; for the French had done every thing in their power to obstruct the passage of the English by sinking two ships, a ketch, a hulk, a snow, and a vessel without any masts, all directly in the channel, within gun-shot of the fort, and laying two booms, moored with chains, across the river.

The Admiral conceiving that a passage might be found between those sunken vessels without weighing any of them, sent by night some expert persons, under the direction of Mr. Delamot, master of the Kent, who, without being perceived by the French, found out a sufficient channel, and cut the booms; which being effected, and the boats on their return, Delamot * hung up a light at the mast-head of one of the sunken vessels, at which the enemy kept up a constant cannonade during the night. On the 24th the Admiral passed through this channel with three ships, and coming abreast of the fort, he anchored; and in less than three hours, after a very brisk firing, the enemy hung out a white flag, and capitulated, notwithstanding they were 1200 strong, had 183 cannon, and

* Perhaps Delamot, to cover his last operation, hung up the light at a distance from the place where he was at work, to draw the enemy's fire clear from the people employed.

three mortars. Captain Latham was sent to receive the keys, and take possession of the fort, and colonel Clive, with the king's troops, marched in about 5 o'clock.

215.

Of the siege of Louisburg, in 1758.

Louisburg is a strong town in the island of Cape Breton; it stands at the SW. end of a very fine bay, which extends NE. and SW. above two miles in length, and is about three quarters of a mile in breadth: the entrance, of about one quarter of a mile broad, is near the middle of the bay; its southern side is formed by a cluster of islands, in one of which stood a large battery, called the Island Battery, of 36 guns; and on the coast opposite the entrance stood the royal battery of 42 guns, with a covered way and glacis before it. In the harbour were 13 sail of ships, most of them lying to the NW. of the town, ready to defend it on the harbour side, and to impede the approaches on the land side: the garrison was about 4,000 strong, had about 220 cannon, 18 mortars, and was well stored with provision and ammunition.

On the 28th of May, the fleet under Admiral Boscawen, and the army under General Amherst, assembled before Halifax, and on the 2d of June they anchored in Gabarus Bay, about two miles to the SW. of Louisburg: but on account of the blowing weather, nothing toward landing could be done till the 8th, when seven frigates drew near shore, and for about a quarter of an hour cannonaded the French defences thrown up along shore; and then the boats landed the troops amidst a very heavy fire, both of the French musketry and cannon, and a most dreadful surf, which overset and staved several of the boats, and drowned many soldiers; and upon the whole there were above 100 boats lost in landing the troops and provisions.

On the 12th, Brigadier Wolfe was sent round the harbour to the north side of the entrance, to construct a battery near the light-house, and thence to ruin the island battery. He drove the enemy from all their defences on that side, took several cannon, and by the 20th had completed the light-house battery, which, with the fire from the ships, silenced the island battery by the 25th. The light-house battery being considerably strengthened by ship-guns, and intrenched, Brigadier Wolfe was ordered round with his detachment and cannon, and to advance toward the west gate, and to try to destroy the shipping. He took post on the hills for that purpose on the 30th.

The 29th, the French sunk four ships in the harbour's mouth with their masts cut down; and on the 21st of July, one of their ships was set on fire by a shot from the marine battery; this fire communicating to two others, the three were burnt. On the night of July 25, Admiral Boscawen detached the boats of the fleet in two squadrons, under the command of the Captains Lafory and Balfour, to take or burn the only two French ships then in the harbour. The boats going silently along the middle of the harbour, the noise of the oars was not heard at land, nor at the ships till the boats were nearly along-side; and then the courage and activity of the seamen rendered all resistance useless: one of the ships,

ships, the *Prudente* of 74 guns, being aground, they set her on fire; and the other, the *Bienfaisant* of 64 guns, they cut from her anchors, and towed into the NE. harbour amid the fire of the musketry and cannon from the town and other places.

In fine, the batteries of the English being opened, well served, and well directed; and the enemy's ships, and many of their defences being ruined; they thought proper to capitulate on the 26th of July, and the English took possession of the town on the 27th.

216.

Of the taking of Quebec, in the year 1759.

QUEBEC, the capital of the French dominions in North America, stands on the NE. bank of the great river St. Lawrence, about 360 miles from its mouth, and on the south side of the river St. Charles; which falling into the river St. Lawrence on the north of the town, forms a fine basin of about three miles in length and breadth; the east and NE. parts are terminated by the isle of Orleans, which is a most delightful and well cultivated spot about twenty miles long and seven broad, formed by the river St. Lawrence. The greatest part of Quebec stands on a rocky hill, in some places near fifty feet above the river; and on a small strand at the foot of the hill is built the part called the Lower Town: the high land stretches up the river St. Charles, and also, with a steep front, for many leagues up the river St. Lawrence. The town was fortified and well defended by many batteries; and an army of about 10,000 men, under the brave and cautious General *Montcalm*, occupied posts well intrenched, at every accessible spot, for an extent of near five miles on the side of the river St. Charles, which was imagined to be the only part where the town could be approached by an enemy: these posts had in front a sand-bank between them and the river, and thick woods in their rear.

The English army, of about 7,000, commanded by General *Wolfe*, was landed by Admiral *Saunders*, who commanded the fleet, on the 27th of June, on the isle of Orleans; and on the 29th of June a detachment drove the enemy from Point Levi, a high promontory on the south shore of St. Lawrence, which commanded the basin, and even the town of Quebec, and from whence the English batteries considerably damaged the Upper Town, and entirely destroyed the Lower one: and about the same time a detachment took possession of the western point of the isle of Orleans, which also commanded the basin. Admiral *Saunders*, with his division of the fleet, was posted below the town in the north channel, and Admiral *Holmes*, with his division, was stationed above the town, to divide the enemy's attention, and guard the batteries playing on the town and works.

On the 30th of June, about midnight, six fireships, well prepared for burning, their sails being covered with a composition that burnt a considerable time, were almost in an instant lighted up, and made a most terrible appearance. They came down with a gentle breeze and a strong tide toward the middle of the fleet, then riding in the north channel, pretty close to one another; but this being expected by the Admiral, the boats were ordered out, and these dreadful machines towed ashore
on

on the Isle of Orleans, where they burnt quietly without doing any mischief. The enemy's next attack was by a raft of fire-stages composed of fir logs, each stage about the size of a long-boat; these were lashed together, filled with combustibles, loaded pistols, and gun-barrels, and turned adrift toward the ships, but with no better success than the other: the whole was about 200 feet long, and made a fine bonfire.

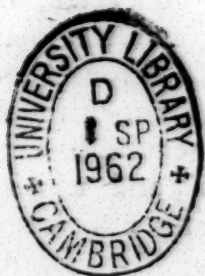
General Wolfe having encamped on the 9th of July at Montmorenci, on the continent below the town, and tried, during almost two months, several ways to bring the enemy to a battle, (all which were frustrated either by the difficulties of the place, or the vigilance of *Montcalm*), determined to try what could be done above the town. He therefore removed the camp to Point Levi on the opposite shore, and Admiral Holmes's Squadron made for several days some movements up the river, the English army advancing at the same time along the southern side; while M. Bouganville, with a body of 1,500 French troops, proceeded along the northern side to watch these motions. On the 12th of September, about midnight, the English were embarked in the flat-bottomed boats, and fell silently down the stream, the enemy being amused up the river by Admiral Holmes. The boats landed on the north side, not exactly where it was intended, and the troops were obliged to scramble up a woody precipice, which however they effected, dispersing a captain's guard posted there, and the army was formed by daylight.

While this was doing, in order to draw Montcalm's attention another way, as had been concerted, Admiral Saunders ordered all the boats of the men of war and transports, well filled with men, to feign an attempt on the French intrenchments below the town. The number of boats, and the manner in which this false attack was conducted, kept the French general too much alarmed to think what might be doing above the town, and which he could scarcely believe when informed of it; but being convinced, he assembled his troops and marched to attack the English. Both armies drew up with great circumspection; and the French advancing, began the engagement with a galling though irregular fire; which was received and borne with great patience, till they were come to the distance of 40 yards; then the English poured in such a well-aimed and dreadful fire, that the French army immediately staggered; and being pushed with a true British spirit, they broke and yielded up the victory. This decisive battle was followed by the surrender of Quebec, by capitulation, five days after; and the English troops took possession of that city and its neighbouring country.

217. The late wars, particularly the last, have furnished many examples of sea engagements, and of the attack of strong places on the sea-coasts; where both the sea and land officers have shewn themselves possessed of all the military knowledge, which good sense and experience could produce, besides that intrepidity so natural to Britons: the few examples here selected, chiefly to illustrate the laying of booms, are neither the most interesting, nor those where British valour

has shone in its greatest splendor : there are many actions of equal importance, and accompanied with as striking circumstances, which may be found among the accounts published on those occasions. This subject cannot be better closed, than with a remark of Admiral Vernon ; That where men of war can be brought to act at a small distance, as about 100 yards, or less, no fort can withstand their fire ; but at a greater distance, as of half a cannon shot, a fort can receive very little damage from the fire of ship-guns.

F I N I S.





Profile thro the Face of a Bastion, its Foss & Glacis

